BROAD LINES IN SCIENCE TEACHING

F. HODSON

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PREFACE

THESE papers deal with the teaching of science to boys and girls of secondary-school age. The editor's object has been to cover a wide field, to achieve, through variety of the contributors' experience, variety of presentation, and so to convince the reader of the many-sided human value of science in modern education. If completeness can hardly be attained in so small a compass, obvious gaps have, it is hoped, been filled. The various writers have drawn attention to requirements which in the ideal case should be satisfied: correlation between subjects and between stages, claims of rival departments of scientific study, claims of heuristic or other methods of teaching, claims of practical application to health, home, and morals; and the bearing of scientific ideas in neighbouring branches of learning has also been touched upon. It has not been shown in detail how far such ideas and requirements are being worked out and met in individual schools or classes of schools.

Readers who wish to know something of this side of the matter may turn, in the first place, to a report which has appeared during the passage of this work through the press.[1] This report, edited by Mr. Latter of Charterhouse,[2] begins with an interesting retrospect, dealing with the development of science teaching at four well-known Public Schools. Then follows an analysis of the replies received from fifty-six schools, in answer to a circular of questions, touching on many points of teaching and organisation; and the report concludes with appendices giving in full a number of courses of work actually in use. It is shown that individual differences are considerable: and this is to be expected and welcomed. We may hope with Mr. Latter that personal interest and enthusiasm will never be sacrificed to a rigid uniformity: in this spirit the present set of papers has been collected.

F. H.

September, 1909.

[1] Board of Education. *Report on Science Teaching in Public Schools represented on the Association of Public School Science Masters*, 1909.

[2] See Paper IV, "Biology in Schools."

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INTRODUCTION

BY PROFESSOR SADLER

AMONG all the movements of thought which have passed over modern Europe, two only, and those separated by a long interval of time, have had in them enough of sustained force to sweep through the whole field of higher education and to give a new aim and method to the schools. The first was the classical renaissance; the second is the study of natural science. Each has worked in the main upon different materials; the one upon the texts and monuments of antiquity, the other upon nature closely scrutinised and comprehensively observed. Each accordingly has in turn developed its own method of investigation and its own canons of evidence. Each has favoured that form of early training which, in the field of study concerned, makes the vision clear, the observation accurately alert, and the critical judgment sound. But in spite of all differences between them in regard to the subject-matter of study and the practical application of its results, the two movements have had in their

origin one characteristic resemblance. Both have been efforts to win for men the right to greater liberty of thought. Both have been inspired by a passion for intellectual freedom and by indignation at obsolete restraints upon the mind. And it is this passionate, human element which has given to each movement in turn its zeal for educational reform and the strength needed for a long struggle against the inertia of prejudice and routine.

What the classical renaissance was to men of the fifteenth and sixteenth centuries, the scientific movement is to us. It has given a new trend to education. It has changed the outlook of the mind. It has given a new intellectual background to life. It has therefore disturbed the old balance of studies. It has broken down a scholastic monopoly. It has made a new learning indispensable to all professional callings. It demands a new spirit and a new method in teaching. Its claims affect the whole field of education and every grade of school. They involve a revolutionary change.

But school systems are by nature conservative. They are rooted in old ways, loyal to established traditions, sturdy upholders of tested experience, critics of what is new and untried. A chief part of their work is to train up those who will carry

on the business of the nation without any break in the continuity of its historical development. That is their trust. They are among the institutions by means of which the old order seeks to hold its own with the future. Most of those who occupy in them the posts of great responsibility are men no longer young. A school system therefore resists a new intellectual movement which challenges its accepted precedents, which demands sweeping changes in its settled administration, which urges a redistribution of its endowments, and which involves a fresh point of view in its methods of instruction. The leaders of the classical renaissance had to fight for generations against the hard-set conservatism of the schools. A great political change was necessary before their victory could be complete. And even then the conservatism of the schools was so tenacious that the new studies lost much of their life and purpose under the pressure of obstinately persistent traditions. In the greater number of schools which were founded under the impulse of the Revival of Learning, the intellectual fire died down at last into mere bookishness and decorous care for literary precedent. How little of the austere grace of mind and person which boys and girls had gained in Vittorino da Feltre's school at Mantua, when

Love's Labour's Lost came to be written, could survive in the sententious pedantry of the schoolmaster Holofernes.

The educational claims of the scientific movement met with the same resistance. The new thing, because it was in essence revolutionary, was repelled by those schools which were the bulwarks of the old order of thought and of social organisation. Faraday declared in 1855 that even the classes which were esteemed to be educated were for the most part not only ignorant of physical science and of its methods of enquiry and judgment, but also ignorant of their ignorance. Five years ago, one who by training and experience is especially qualified to judge in such a matter, said: "It is a fact, and a very strange fact, that although we are living in a scientific age, anything approaching to a knowledge not of the general principles but of the methods and results of any one department of science is extremely rare among educated men."[1] He was speaking of those whose calling lies outside the strictly scientific professions, and who have been educated in places where the old scholastic tradition is strong. The change during the last fifty years has, it is true, been enormous.

[1] P. N. Waggett, *The Scientific Temper in Religion* (London: Longmans, 1905), p. 34.

But, in England, the spirit of science has not yet permeated the higher schools, at any rate the higher schools for boys. Science has secured a place in their curricula, a firm place and respectful recognition,[1] but scientific method and the spirit of science have not yet influenced the whole of the intellectual life of the schools, have not yet remoulded the ways of teaching in other than what in the narrower sense of the words are called scientific subjects. There is still in these schools (and in many others affected by their example) a discontinuity, which indeed is in some degree unavoidable, between the subject-matter of the scientific courses and that of the other parts of the curriculum. But worse than this, there is a conflict of presuppositions, a difference in intellectual focus, which could be greatly lessened, and which, even when not consciously realised, is injurious to those who learn.

The situation as regards the teaching of science in English schools has been affected by the course of our educational history to a degree which calls for explanation. We have in fact no administrative unity in our national education. Two great systems of schools exist side by side,

[1] See the *Report on Science Teaching in Public Schools represented on the Association of Public School Science Masters*, edited by Mr. O. H. Latter for the Board of Education (London: Wymans, 1909).

those under State inspection and those which are not so inspected. In the course of the last century, the first of these systems has grown with extraordinary speed, and now, in point of size, is to the other what a giant is to a man. But the smaller group of schools which is not yet under regular inspection by the State (I exclude in this connection that large proportion of private schools which concerns itself with elementary work alone) enjoys social pre-eminence and retains a large measure of political influence. This group is semi-independent of State control. Parliament has subjected it, at two stages, to public enquiry. Its expenditure of old endowments, its forms of self-government, and in a rather vague way its courses of instruction, are regulated by statute. But its general position is quasi-public rather than public, in the sense that no Government department keeps its work under inspection and continuous review. There have of course been great advantages in this different treatment of two great groups of schools. But one of the serious drawbacks to it has been the weakness of public pressure upon the higher secondary schools for boys, and upon the preparatory schools which do the initial stages of their work, in respect to the place of natural science in the regular curriculum. The old

scholastic tradition has been protected in them by the attitude of non-interference adopted by the State. In all the schools which are periodically inspected by Government and which carry on their work under regulations laid down from year to year by the State, natural science has a place of greater relative importance in the course of study than is yet the case in the large majority of the schools which are exempt from this direct form of pressure. Our English system of State-aided and State-inspected education grew into its full stature during the period in which natural science had already become the most potent intellectual influence of the age. The fact that most of those who in Parliament framed the plan of the new system, and of those who administered it from the public offices, had themselves been trained under a system of education which included but little natural science, delayed for a time the entrance of the new ideas into many of the schools concerned. But the influence of the Science and Art Department (officered almost entirely by men who had received a scientific training), the needs of industry, and the strong trend of public opinion overbore this temporary resistance and neglect. The result is that one of the first aims prescribed by Government for every public elementary school is the "careful

training of the children in habits of observation and clear reasoning, so that they may gain an intelligent acquaintance with some of the facts and laws of nature." And every secondary school, in order to be recognised as efficient by the Board of Education, must submit for the Board's approval "a curriculum (with time-analysis) of the whole school, providing for due continuity of instruction in each of the subjects taken and for an adequate amount of time being given to each of these subjects," while it is farther required that the curriculum must include, among other subjects, science with practical work.

Step by step the State has advanced towards a comprehensive treatment of national education. At first it confined itself, in the main, to the schools intended for the labouring poor. These schools, once systematically aided out of public funds, rapidly grew in number, in importance, and in range of intellectual effort. Next, evening and other classes for scientific and technical instruction were liberally aided by the State. The beginnings of higher education for the people were thus secured. Government then found itself compelled to encourage a new type of secondary day school as a superstructure to the elementary schools and as a link between them and the technical classes. In 1890 funds

were forthcoming, under the Local Taxation (Customs and Excise) Act, which enabled the Technical Instruction Committees to aid the scientific side of the work of the local secondary schools. Finally, the Education Act of 1902 gave to local authorities in county and county boroughs throughout the country the duty of co-ordinating the schools, elementary and secondary, within their respective areas. The effects of the Act have been momentous. The plan of a national system of education has been, in great measure, administratively realised. A greater impetus has been given to secondary schools than at any time since the Revival of Learning. In form at any rate, if not in substance, the scientific movement has won its victory over almost the whole area of English education. And those of the endowed schools which still remain outside the province of Government inspection are like scattered islands in a great sea.

But in the very moment of victory some of the best friends of science teaching felt misgiving and disappointment. Was the science which had thus won its place in school curricula being taught in a way which kindled intellectual interests and prepared those who learnt it for the work of independent thinking? Had it, in spite of laboratories which gave opportunities for practical

work, merely taken its place, in most instances, in the ranks of other "subjects" and become but a new branch of the old scholastic routine? And what was the reason why so many of those who had been trained through natural science failed in the power of self-expression and were consequently weak in the accurate presentment of things observed? At this point Professor Armstrong and Professor Perry shook us out of a dogmatic slumber. And many strong advocates of the claims of natural science to a predominant place in secondary education admitted the value of the old scholastic tradition, for the reason that, at its best, it cultivates the power of expression by exact linguistic discipline and opens the mind by humanistic studies to a wider view of life.

Thus the present is a time of reconciliation between two schools of thought which had long been separated and often bitterly opposed. Each has come to a better understanding of the aims of the other. We are passing through a period of truce. Those whose experience has lain in schools of the new type appreciate the value of the humane and literary ideals which are the real distinction of the older tradition in secondary education. Those on the other hand whose experience has lain in the older type of school admire the intellectual vigour—especially shown in scien-

tific and practical work—which characterises many of the new. It is felt that what is needed is a combination of the best in the two traditions, a fusion which is more possible now than at any earlier time.

But such a fusion cannot easily be brought about. The most threatening evil in modern education is multiplicity of studies, imperfectly related to one another and at too frequent intervals changing the focus of the mind. The most hopeful way out of the difficulty caused by this pressure of many subjects upon a necessarily limited time-table lies through the study of methods of teaching, with a view to the closer dovetailing of related branches of knowledge, to the excision of those parts of each subject which can be omitted without destroying the continuity and discipline of the instruction, and to greater precision and economy in the lines of intellectual approach. The rapid growth of interest in the study of methods of teaching is therefore one of the most encouraging, as it is one of the most significant, of recent developments in English education. It has come at the time when it was most needed. It has shown itself in every grade of education. It has been encouraged by nearly all the associations of teachers. The professional journals have furthered it. It is showing itself in

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discussion, in the publication of experience, and already, to some degree, in systematic experiment. Towards the study of one aspect of the subject this book is a contribution.

II

The writers of the following chapters desire to see the scientific habit of mind and the scientific way of looking at things more carefully fostered in English education, especially in that part of it which still lies under the dominant influence of the old scholastic tradition. They are far from claiming for physical science a preponderant part in the course of general education which should precede any form of specialised study. Language and literature, history, art, and music are in their view indispensable factors in a liberal education. But they hold that on educational grounds the study of nature should also be a necessary part of the school training of every child. They feel moreover that, as Faraday said, everything depends upon the spirit and manner in which scientific instruction is given and honoured. They wish to see school work and the conditions of school life imbued with science. They believe that in the encouragement of the scientific temper and attitude of mind lies one of the best

hopes of culture, the surest guarantee of intellectual activity and of temperate judgment in the nation, and one necessary means of preparation for the duties of citizenship. They have therefore brought into common stock their experience of the ways in which the study of science may become, directly and indirectly, a vitalising influence in the work of a school.

It will be seen, therefore, that this book, while mainly concerned with the methods of teaching science, addresses itself also to other fundamental questions which are involved in any study of the right relation of the growing mind towards new knowledge, new duties, and new kinds of action. Mr. Badley sets this larger view before us in the first chapter. The true aim, he urges, in the preliminary teaching of science is not to give a mass of facts to be remembered, but to train the pupil to a right habit of investigation and of inference. And he strikes the key-note of the book in his argument that science should not be divorced in the children's minds from the actual happenings of everyday experience in house and garden. This is the synthesis which makes science teaching real. Science (though in part focussed in certain lessons and practical exercises) is not to be treated as a separate compartment of a programme of studies. It is the gaining of a

habit and attitude of mind, partly through prescribed lessons, partly through voluntary occupations, partly through the medium of practical duties done (with understanding of the scientific reason for them) by the pupil in the service of the school-community of which he is a member.

Dr. Hodson points out in one of his contributions to the volume that the teaching of science in pre-university education falls into three stages —one extending from early childhood to the age of twelve or thirteen; the second covering the period up to about sixteen; and the third (of varying length according to the duration of the pupil's school-life) comprising the remainder of his course. Following this order of treatment, the book begins, after Mr. Badley's opening chapter, with articles upon the scope and teaching of nature-study by Mr. Edward Thomas and Miss von Wyss. The essays on nature-study, which is largely concerned with the study of living things, lead to Mr. Latter's paper upon the teaching of biology. He shows how cogent are the reasons for regretting the present comparative neglect of biological studies in secondary schools. Closely akin to Mr. Latter's argument is that put forward in the following essay by Miss Alice Ravenhill upon the teaching of hygiene. She raises, among other matters of

the highest educational importance, the pressing question how, through the teaching of hygiene, boys and girls may receive instruction as to the right conduct and transmission of life. The following chapters in the book deal with problems of educational method. A deeply interesting question in intellectual ethics which presents itself to many teachers of science in schools is examined by Dr. Percy Nunn in his essay on "The Place of Hypotheses in Science Teaching." Dr. Hodson reviews the often conflicting claims of "research" work and examinations, and, while strongly recommending a judicious but thoroughgoing use of the heuristic method up to about sixteen, points out the need, when the examination stage is reached, for "a speedier method of accumulating experience" which may be followed up by interesting individual work in free time. He illustrates from the practice in his own laboratory this method of counteracting the tendency of examinations to put an undue pressure upon receptivity, but frankly admits that "the more coherent, deductive ordering" of a subject, which preparation for an examination requires, is (if not dominant in the school course and if it is postponed to the later stages of instruction) not unwelcome or without benefit to some of the most active minds. In the following paper,

which also draws freely from the writer's long experience in working out new methods of instruction, Mr. T. J. Garstang discusses the teaching of mathematics in schools, emphasising the great importance of preserving a large place for "the inductive process as a vital factor in promoting healthy and vigorous growth of mind during the early years of youth" and showing ways in which the mathematical teaching may be closely correlated with that of physical science. This leads to Mr. Porter's paper on the co-ordination of physics teaching in school and college, which in turn is followed by an essay on the teaching of geography by Mr. Stephenson, who agrees with Mr. Mackinder that "the object of the teacher is to build up a conception of the surface of the earth as a product of interacting forces, in order that that surface may be intelligently viewed as the scene of social activities." In the next essay Professor Powicke discusses the place of scientific method in the teaching of history, pointing out how great is the value of story and legend in stimulating the power of imagination, but demurring to any attempt at serious and systematic history teaching being made before the later years of school life. "When the teaching does begin, it should be real. The teacher must know his work through and through.

. . . There should be no hurry at school to fix and define the sequence of civilisation, but there should be great care to make the different stages real and living." The larger use, in the teaching of arithmetic, of illustrations drawn from economics, and the best methods of teaching domestic science to girls are discussed by Mr. Kahn and Professor Smithells in the succeeding chapters; the teaching of the sciences bearing on agriculture and of engineering in those which follow. A very important aspect of the question is then raised by Mr. Sidney Unwin in his paper on "Science Teaching and the Training of the Affections." He shows how much scientific training may be gained through compulsory practical work, including poultry and bee-keeping, farm and garden occupations, as well as through hobbies. He also points out how the conditions and studies of school life may be so organised as "to unfold to our boys the mysteries of birth and growth." His paper, based upon much experience, will impress the reader with a strong sense of the possibilities of co-education, when carried on with close interest and care, as a means of safeguarding a good moral tone. Another step in the cumulative argument of the book is taken by Miss Sanders, who writes about the influence of wise science teaching upon a

child's philosophy and religious ideas. She pleads for the giving to every child of the best we can of science (including some early teaching of biology) and the fullest instruction in religion, not least in acts of reverent, common worship. Studies of the present position of science teaching in the United States and in Germany, suggestive as showing the similar trend of experienced opinion in those countries and our own, and practical notes on the planning of science laboratories in schools complete the volume.

III

In conclusion, a few words should be added as to some of the practical inferences which may be drawn from the book.

It is right to give very much discretionary freedom to the competent teacher in working out new methods of work for his class, and to allow him much liberty in experimenting in the omission of parts of his subject from the course of instruction. It would be a mistake to hamper the teacher by elaborate syllabuses imposed by an external authority. The willingness of the Board of Education to give freedom to the skilled teacher is wise and fruitful.

If science is to have a strong intellectual in-

fluence upon the whole body of school-work, it is essential that men and women of the highest ability and competence should be encouraged to devote themselves to service in the secondary schools. This will not be the case unless, through pressure exerted by the State, a great improvement is quickly made in the salaries and professional prospects of the assistant teachers in the large majority of those schools throughout the country. This is one of the most urgent, perhaps the most urgent, question in national education at the present time. We are spending large sums upon the material equipment of secondary education, but relatively too little upon the human factor which is vital to its welfare.

The more general introduction of biology into school studies should, on educational grounds, be specially encouraged.

It is important that attention and aid should be given to the development of well-arranged courses in domestic science in the secondary schools for girls (especially as a supplement to the ordinary school course), and to the training of teachers in this subject.

The argument in favour of the co-education of boys and girls, in boarding schools as well as in day schools, is being strengthened by a growing

volume of experience, provided that it is carried on under conditions of wise and very careful oversight, and with due regard to their different needs in point of study and exercise.

The comparative neglect of preliminary science teaching in the preparatory secondary schools for boys is a grave defect in national education. Mr. Latter points out in his *Report on Science Teaching in Public Schools* that "It is no uncommon occurrence for a boy, clever at classics and mathematics and therefore placed in a relatively high form on entry to the Public School, to have done no science whatever. Total inexperience of science is more common among these clever boys than among their less favoured brethren. Nor is the reason far to seek. Science finds no place in the examination for the valuable (classical) entrance scholarships awarded by the Public Schools. There is thus a strong financial temptation both to parents and masters of Preparatory Schools to neglect the subject which does not pay." The study of nature should form an indispensable part of the early education of every child. But in present circumstances the early education of some of the most promising boys in the country is injured by a prematurely specialised curriculum, in which linguistic and mathematical training holds too large a place,

with the result that the study of nature and manual training are unduly neglected. The remedy for this evil cannot be found without considerable changes in the present methods of awarding entrance scholarships at the great Public Schools. This may call for action on the part of the State. But administrative reforms, necessary as they are, will not bear full fruit unless there goes with them a change in the point of view of many parents and teachers, such a change as would accompany a wider diffusion of the scientific temper of mind.

What, then, are the distinctive marks of the scientific temper of mind which it is so necessary to encourage in education? Among many characteristic signs of it, four seem to be primary and essential—an alert interest in things seen; patience and exactitude in observing, verifying, and recording them; a disposition to brood over new facts before reaching a judgment as to their meaning and classification; and an habitual willingness to take great trouble in getting at the truth. These qualities and powers of mind have in a signal way proved their value in the pursuit and application of natural science, but they are not less efficacious in many other branches of study and practice. Experience has shown that one necessary instrument in their

training is found in the first-hand study of nature. But the direct contact with nature which is thus necessary to a liberal education must be held to include, as an indispensable influence in its discipline, intimacy with living people through whom the learner gains direct experience of the beliefs and ideals in which men find strength and hope; under whose authority he learns how to observe and to verify; and from the working of whose minds he assimilates almost unconsciously the power of rightly using his own. It is a sterile form of scientific training which takes little regard of human relationships, and a narrow kind of humane education which ignores the study of nature. A liberal education draws its energy from many sources, doing its work (as Ruskin said) through "the study of nature, the sight and history of men, and the setting forth of noble objects of action."

M. E. SADLER.

BROAD LINES IN SCIENCE TEACHING

I

THE PLACE OF SCIENCE IN THE SCHOOL CURRICULUM

By J. H. BADLEY, M.A.

THE battle for the admission of Science into the school course has been fought and won. No one now disputes that it has a place, even though by some staunch adherents of the old school of classical culture its place may be grudgingly conceded, and kept as small as the clamour of commercially minded parents will allow. This is, perhaps, the less to be wondered at when we remember that the advocates of Science have been as sweeping and one-sided in their claims as its opponents. Herbert Spencer, the high priest of scientific dogmatism, in the most widely known of his writings put the question, "What knowledge is of most worth?" and after discussing the bearing of knowledge on earning a livelihood, health, citizenship, art and mental discipline, gave on

every count the answer—"Science." Science, according to his claim, must henceforward form the basis, and occupy the larger and more important part of the school curriculum, and such side-interests as literature and the arts might be allowed to occupy the leisure part of education, as of life.

Here was a turning of the tables, indeed, upon the classical school; and in their revolutionary zeal some of the supporters of Science have endeavoured, so far as the deadweight of prejudice in favour of the humanities and old-established custom would allow, to realise this ideal. They admit, of course, the need, duly subordinated, of other subjects; of mathematics, naturally, as a sister science and the most powerful of instruments in the physical sciences; of some foreign languages, necessary for keeping abreast of contemporary discovery and thought; of the use of books, for reference; perhaps even of some command of the mother-tongue, in order to describe experiments and convey discoveries to others; and of drawing, of a strictly utilitarian kind, to help to record and present them. But anything conducive to literary and artistic enjoyment, as able to amuse only the leisure of the few, they would leave to these to find for themselves, apart from the serious business of life and education.

The foregoing sketch of a school course, drawn

up on the lines of Herbert Spencer's claim for Science, is, happily, a fancy picture, or at most a caricature of the reality. But, after all, it is not so unfair a statement of the demands advanced by some teachers, as well as by many men of business and parents who want quick returns for the cost of education in the shape of knowledge that will pay. And let it be at once admitted that they are fully justified in claiming a place for Science in the school course on this ground. So much of modern industry and business, and, indeed, of most sides of modern life, is not only based on the discoveries of Science, but depends for efficient performance on a practical knowledge of some or other of its branches, that education without any knowledge of Science is now, whether for boys or girls, well-nigh as unpractical and absurd as it would be without any knowledge of the "three R's." There are other reasons, and weighty ones too, for including it in the school curriculum; but this reason alone, its utility and direct bearing upon many of the activities of modern life, is real enough to justify the demand for giving it a place, and a large one, in education. But that is a very different thing from making it the sole basis of education, or even for making it the chief means of training for all alike. That would be every bit as narrow and inefficient and—in the widest sense—as unpractical as the old classical

training. In the first place, we cannot all find our interest and our best training in scientific research any more than in writing Latin verse; nor, for that matter, is it necessary that we should, for in these days of highly specialised knowledge, we must be content to call in the expert in the particular branch of applied Science that we need, just as we call in the doctor. What is necessary is that we should have some modicum of scientific knowledge and training to enable us first to appreciate the value of his advice, and then to follow it intelligently. And, in the second place, whether or not we follow some career for which a scientific training may be specially needed, we are in any case to be human beings and share the joys and sorrows and common interests of humanity; so that there is still, when we have admitted all that can be urged for the utility of Science, a place left in education for the "humanities," the literary, artistic, and social studies whose main purpose is to enrich our lives with higher ideals, nobler motives, and wider sympathies.

The fact is that both sides in the dispute have been too ready to base the claims of Science solely on its practical utility, and to ignore the real grounds on which the educational value of Science, as of any other subject in the school curriculum, must be determined. These are threefold: the kind of motive it appeals to and arouses, the kind of power that it develops, and

the kind of discipline that it gives. Tried by these tests, the claims for Science are at once seen to be well founded. Its appeal to the instinct of curiosity, to love of experiment and delight in machinery, is instant, and, one may almost say, universal; and to some, at least, it offers the fullest satisfaction of the highest motive that can inspire man's work—the service of his fellows. Again, the power over material things and over the instruments of knowledge developed by Science and scientific method is one of the chief wonders, as it is one of the commonplaces, of our time; while the discipline that the study gives is, in some respects (owing to the nature of the material with which it deals), superior to that given by any other. But in admitting all this on behalf of the educational value of Science, we must not forget that it does not apply to all cases alike. If to some the knowledge of Nature's workings is the one really interesting thing in the world, to others it is only, as it were, the dissection of a living beauty that, in striving to explain, it can only destroy. Granted the power that it gives, power of that kind (for we must not make the old mistake of supposing that the power trained by exercise in one subject is like that trained by another kind of exercise, or that it can be applied at will to other things and exercised in other ways) is, as I have already pointed out, neither needed by all, nor, even if

desired, always attainable. There are some minds to which it seems as little possible as linguistic and literary skill to others. And, finally, invaluable as is the particular discipline the study of Science can give, where it is followed with real interest and intelligence, when this is *not* the case no more can be said for this subject than for Latin or any other that is little liked and little understood; both can give a discipline of a kind—and a necessary kind too—the discipline of doing something that we do not find easy or pleasant; but this kind of discipline, even if good for character, is dearly bought at the cost of the mental stagnation that accompanies it if given in large doses; and besides, it can be given in other ways less costly, both in money and in teaching power, than the study of Science by those who have not either the wish or the power to carry it far.

Are we then brought back to some compromise between the opposing claims of Science and the humanities, such as that existing at the moment in the Public Schools, of a classical training, without Science, for some, and a modern side, admitting it in varying degrees, for others, and a "pull-devil, pull-baker" tug-of-war between them for the best brains, with tradition and social standing to help the one side, and "a sound commercial training" on the other? I confess that to me this compromise seems eminently unsatisfactory, and I believe it to be only a temporary phase in the re-

adjustment, everywhere going on, of education to national needs. I believe that we shall come to see that Science is far too valuable an element of education to be left out in any single case. For some—for the majority I have little doubt—it must not only form part of the general foundation course on which any later lines of specialisation must be built, but also, in some of its many branches, furnish the chief means of that later specialisation. But even for those who will turn away from the pursuit of Science at this last stage, and devote themselves to the more literary studies, I hold that a preliminary course of Science is no less valuable and no less necessary. In the first place it is necessary in order to enable the child to discover, or reveal, his natural bent and aptitude—the discovery of which depends so much on opportunity for trial and presence of sufficient stimulus. We must not take for granted that natural aptitude, like murder, always "will out." If strong, of course it will, under any circumstances; but most children have not got strong aptitudes, and yet have some, though they may not be strong enough to come out under adverse circumstances. Many a boy who goes through the classical course without special interest or ability, and finally drifts into one of the "learned" professions, which he only helps to overcrowd, or into office-work, because, though he cannot do that with success, he has learned

to do nothing else—to say nothing of the still completer failures—might, if he had had a wider range of interests opened to him at school, have discovered aptitudes which, as it was, lay untouched until they became useless for want of exercise. I need hardly stop to point out that a similar atrophy of powers and motives might take place if we thought to remedy matters by simply substituting Science in the place hitherto held by the dead languages. The general course would still be too narrow. We want in this earlier stage that covers, for most, the chief years of school training—those up to the age of fifteen or sixteen—as wide a course as is compatible with real work and real progress (and that is more a matter of teaching methods than of the number of hours devoted to it) in each subject taken up, so that no power or interest the child has may be entirely untouched and undetected. In this course Science must have a place, and not for this reason only. Science is a valuable part of education not only from its practical utility and its appeal to so many living interests, but also as an important element in general culture. In an age when scientific discovery is progressing with extraordinary rapidity, when scientific ideas are not only themselves undergoing constant development, but are transforming our ideas on most other subjects as well, when the methods of Science are being applied to all branches of

enquiry, and its theories form no small part of the intellectual background of our thoughts, one who had no knowledge of the conceptions with which Science deals, its methods of enquiry and the generalisations to which it leads, would be, so far as the intellectual culture of the time is concerned, a pauper and an alien. This I take to be one of the main purposes of that part of education that lies within the school: not only to develop a sound body and sound character, not only to equip for doing some work in the world, but no less to give, or at least to begin to give, some power of obtaining and dealing with new knowledge, and some breadth of interest and mental background to give it perspective and bring it into relation with the rest. And this is the real ground for making Science, in some form, a necessary part of education for all, not only for the future specialist. Quite apart from its practical value in the greater part of the world's work, we cannot do without some training in scientific method, and some background of scientific knowledge, any more than we can do without some knowledge of history and literature, to enable us to enter the world of thought and feeling, and be more than wage-earners or idle pleasure-seekers, but men and women whose eyes are opened to something of the wonder and beauty, and something of the meaning, of the world in which we live.

If this point of view is accepted, we are now in a position to answer more definitely the question how large a place Science should occupy in the School curriculum. It is assumed that it should form a part, and a considerable part, for all, during at least a part of the school course. If together with Science we reckon mathematics—taught, in the earlier stages at least, as an experimental science in which nothing is accepted without direct evidence, and submitted to the fullest possible verification—and also the various kinds of practical work (gardening, cookery, care of animals, woodwork, measurement of all kinds, and so on), out of which Science should grow, and which should be intimately connected with it throughout the whole course, this group of subjects should, it seems to me, in the earlier or general stage of education, up to the age of sixteen or so, occupy as large a place in the school time-table as the other equally important group of studies dealing with language, literature, and the arts. After this age the equal balance of the two groups need no longer be maintained; it is better then, as the time when ambitions begin to awake and the needs of the future career become more evident, to let the main part of time and effort be given to those studies which bear more directly on these needs—though never to the entire neglect of some belonging to the other group; in order that, while the real interests and capacities

may now be developed to the utmost, we should not let any narrow view of practical utility in the form of professional or examination requirements lead teacher or parent or pupil to forget that behind and beyond these lie the requirements of life itself, among which some range of powers, of interests, and of motives is by no means the least.

But to decide how much time shall be allotted to a subject in the school time-table is, after all, of minor importance; what matters is the way in which the time is spent. I confess to being one of those in whose view method of teaching is more important than subject-matter. And here again the *why* must determine not only the *what*, but the *how*. In the later stages, where specialisation is not only permissible, but necessary, each branch of Science that is taken must be taught as thoroughly as possible. That is the time when we want the boy to know, if not quite "everything about something" (we are not quite so blind or so conceited as that), at least as much as we can teach him, or—to put it better—as much as with our help he can teach himself. But in the earlier stages our aim must be quite different, to teach him something about—well, not *our* "everything," perhaps, but *his* "everything"—the external world as it presents itself to him; not, that is, in the form of "botany" or "mechanics" or "electricity," still less as

"matter," "force," "gravitation," "evolution," and the other ways in which we cheat ourselves into supposing we know all about a thing by naming it; but rather in the form of interest leading to investigation of all his surroundings, probably viewed at first (as by his ancestors before him) under the guise of the old "four elements," and still more probably realised as *living* nature, what things do rather than what they are, and especially the way in which plants and animals behave. To the child it is all "nature-study," without division into separate "sciences"; and though the teacher must have some system in the lines of investigation followed, there is no need to make the child conscious of it until the need of some such division presents itself to him. Then the different lines of investigation will gradually narrow themselves down into separate "sciences"—probably following the main lines of their historical development, until finally the time comes for conscious choice, in view of their number and growing complexity, of some special group to study more particularly for a time.

And throughout the whole of this general course of gradually systematised enquiry there are, it seems to me, two main principles of method to keep in mind, arising, as I said just now, from the main purpose that we have in view in admitting Science, in any form, into the school course.

The first principle is that what we want to give is rather a scientific training than a mass of facts to be remembered. In other words, it is the method of investigation that is the main thing, the method of procedure by observation, experiment, and inference, followed by some attempt at verification, and resulting in some "working hypothesis" or general law, itself to be made the subject of further experiment and verification. I do not, of course, mean that the method is to be explained, or any such nomenclature used about it; what I mean is that it must from the very first be a method of research, of finding answers to one's own questions, and so of gradually discovering how to set about finding answers to questions, and thus becoming master of a method that can be applied to other subjects and other kinds of enquiry. It does not matter whether we call the method "heuristic" or not. Names are generally the cause of bitter controversies—more often than the facts that they stand for, because to none of the disputants does the name cover or convey quite the same set of facts. Whatever we call it, this is the true scientific method, and to teach *that* is the chief value of Science in the school.

The second principle of which I spoke is that Science should not be divorced in our children's minds from the actual happenings of everyday experience: that chemistry, for example, is not something unusual that takes place in test-tubes

in a laboratory, but the investigation (by such means as these) of things taking place all round us, conditioning visible changes of obvious interest to us. For that reason, as I said, the Science in the class-room and practical work must go hand in hand. The garden is the real starting-point of one half of Science, as the house is of the other. We want our pupils to realise continually that all their investigations in the class-room or laboratory have a direct bearing upon life and direct applications to every kind of work, and at the same time a remoter bearing on other kinds of knowledge. So that, while on the one hand we want, as one result of our teaching, to bring chemistry into the kitchen, and the scientific habit of mind into all our everyday life, and, as another result, to give some power of appreciating such problems as those that underlie improvement of the aeroplane, the motor vehicle, wireless telegraphy, and other inventions of our time; on the other hand, we want also to lead to some comprehension of the great generalisations, such as evolution, or the conservation of energy, or the bacteriological nature of disease, that underlie all modern thought. It would, of course, be absurd to suppose that all this can be done with every child, and by the age of sixteen. What is wanted is that these lines of enquiry should be so selected, and so followed, as to make something of this possible, according to the

capacity of the learner, even to those who will not be, in any sense, scientific specialists ; and so also, let me add in conclusion, that the result of all our Science teaching should be to give, not the conceit of knowledge, but an intellectual humility that recognises that all we can know and do does but open up fresh horizons of the limitless unknown.

II

THE SCOPE OF NATURE-STUDY

By EDWARD THOMAS

WHAT is to come of our nature teaching in schools? What does it aim at? Whence does it arise? In part, no doubt, it is due to our desire to implant information. It is all very well for the poet to laugh—

> When Science has discovered something more,
> We shall be happier than we were before;

but that is the road we are on at a high rate of speed. If we are fortunate we shall complete our inventory of the contents of heaven and earth by the time when the last man or woman wearing the last pair of spectacles has decided that, after all, it is a very good world, and one which it is quite possible to live in. That, however, is an end which would not in itself be a sufficient inducement to push on towards it; still less can such a vision have set us upon the road.

Three things, perhaps, have more particularly persuaded us to pay our fare and mount for somewhere—three things which are really not

to be sharply distinguished, though it is convenient to consider them separately. First, the literary and philosophic movement imperfectly described as the romantic revival and return to nature of the eighteenth and nineteenth centuries. Poets and philosophers need private incomes, state porridge, and what not; but literature and philosophy is a force, and for a century it has followed a course which was entered in the period of the French Revolution. This literature shows man in something like his true position in an infinite universe, and shows him particularly in his physical environment of sea, sky, mountain, rivers, woods, and the other animals. Second, the enormous, astonishing, perhaps excessive, growth of towns from which the only immediate relief is the pure air and sun of the country, a relief which is sought by the urban multitudes in large but insufficient numbers for too short a time. Third, the triumph of science, of systematised observation. Helped, no doubt, by the force of industrialism—to which it gave help in return—science has had a great triumph. At one time it was supposed to have fatally undermined Poetry, Romance, Religion, because it had confused the minds of some poets and critics.

These three things considered, Nature-study is inevitable. Literature sends us to Nature principally for Joy, joy of the senses, of the whole frame, of the contemplative mind, and of

the soul, joy which if it is found complete in these several ways might be called religious. Science sends us to Nature for Knowledge. Industrialism and the great towns send us to Nature for Health, that we may go on manufacturing efficiently, or, if we think right and have the power, that we may escape from them. But it would be absurd to separate Joy, Knowledge, and Health, except as we separate for convenience those things which have sent us out to seek for them; and Nature teaching, if it is good, will never overlook one of these three. Joy, through Knowledge, on a foundation of Health, is what we appear to seek.

There is no longer any need to hesitate in speaking of joy in connection with schools. Yet might we not still complain, as Thomas Traherne did two hundred and fifty years ago:—

> "There was never a tutor that did properly teach Felicity, though that be the mistress of all other sciences. Nor did any of us study these things but as aliena, which we ought to have studied as our enjoyments. We studied to inform our knowledge, but knew not for what end we so studied. And for lack of aiming at a certain end we erred in the manner."

If we cannot somehow have a Professor of Felicity we are undone. Perhaps Nature herself will aid. Her presence will certainly

make for felicity by enlarging her pupil for a time from the cloistered life which modern towns and their infinite conveniences and servitudes encourage. Tolstoy has said that in the open air "new relations are formed between pupil and teacher: freer, simpler, and more truthful"; and certainly his walk on a winter night with his pupils, chatting and telling tales (see *The School at Yásnaya Polyána,* by Leo Tolstoy) leaves an impression of electrical activity and felicity in the young and old minds of the party which is hardly to be surpassed. And how more than by Nature's noble and uncontaminated forms can a sense of beauty be nourished? Then, too, the reading of great poetry might well be associated with the study of Nature, since there is no great poetry which can be dissevered from Nature, while modern poets have all dipped their pens in the sunlight and wind and great waters, and appeal most to those who most resemble them in their loves. The great religious books, handed down to us by people who lived in closer intercourse with Nature than many of us, cannot be understood by indoor children and adults. Whether connected with this or that form of religion or not, whether taken as "intimations of immortality" or not, the most profound and longest remembered feelings are often those derived from the contact of Nature with the child's mind.

Of health, though there are exactly as many physicians as patients, it is unnecessary to say anything, except that one of the pieces of knowledge—I do not speak of information—which science has left to us is that movement and the working of the brain in pure air and sunlight is good for body and soul, especially if joy is aiding.

Knowledge aids joy by discipline, by increasing the sphere of enjoyment, by showing us in animals, in plants, for example, what life is, how our own is related to theirs, showing us in fact our position, responsibilities, and debts, among the other inhabitants of the earth. Pursued out of doors, where those creatures, moving and still, have their life and their beauty, knowledge is real. The senses are invited then to the subtlest and most delightful training, and have before them an immeasurable fresh field, not a field like that of books, full of old opinions, but one with which every eye and brain can have new vital intercourse. It is open to all to make discoveries as to the forms and habits of things, and care should be taken to preserve the child from the most verbose part of modern literature, that which repeats in multiplied ill-chosen words stale descriptions of birds and flowers, etc., coupled with trivial fancies and insincere inventions. Let us not take the study, the lamp, and the ink out of doors, as we used to take wild life—having killed it and placed it in spirits of

wine—indoors. Let us also be careful to have knowledge as well as enthusiasm in our masters. Enthusiasm alone is not enthusiasm. There must, at some stage, be some anatomy, classification, pure brainwork; the teacher must be the equal in training of the mathematician, and he must be alive, which I never heard was a necessity for mathematicians. But not anatomy for all, perhaps; for some it may be impossible, and a study of colours, curves, perfumes, voices —a thousand things—might be substituted for it.

Yet nature-study is not designed to produce naturalists any more than music is taught in order to make musicians. If you produce nothing but naturalists you fail, and you will produce very few. The aim of the study is to widen the culture of child and man, to do systematically what Mark Pattison tells us in his dry way he did for himself, by walking and outdoor sports, then—at the late age of seventeen—by collecting and reading such books as *The Natural History of Selborne*, and finally by a slow process of transition from natural history into "the more abstract poetic emotion . . . a conscious and declared poetical sentiment and a devoted reading of the poets." Geology did not come for another ten years "to complete the cycle of thought, and to give that intellectual foundation which is required to make the testimony of the eye, roaming over an undulating surface, fruitful

and satisfying. When I came in after years to read *The Prelude* I recognised, as if it were my own history which was being told, the steps by which the love of the country boy for his hills and moors grew into poetical susceptibility for all imaginative presentations of beauty in every direction." The botany, etc., would naturally be related to the neighbourhood of school or home; for there is no parish or district of which it might not be said, as Jefferies and Thoreau each said of his own, that it is a microcosm. By this means the natural history may easily be linked to a preliminary study of hill and valley and stream, the positions of houses, mills, and villages, and the reasons for them, and the food supply, and so on, and this in turn leads on to, nay, involves, all that is most real in geography and history. The landscape retains the most permanent marks of the past, and a wise examination of it should evoke the beginnings of the majestic sentiment of our oneness with the future and the past, just as natural history should help to give the child a sense of his oneness with all forms of life. To put it at its lowest, some such cycle of knowledge is needed if a generation that insists more and more on living in the country, or spending many weeks there, is not to be bored or to be compelled to entrench itself behind the imported amusements of the town.

III

THE TEACHING OF NATURE-STUDY[1]

BY CLOTILDE VON WYSS

EVIDENCE is not wanting, that during the mental growth of any individual, there is a revision of the chief tracks and phases in the evolution of any human activity, and that the training which recognises and follows most closely the same broad lines is the most efficient and successful.

Thus tracing the course of the evolution of the scientific interest backwards, it is clearly discernible, that our academic sciences have had their origin in investigations which are undertaken chiefly for purposes of practical utility, and that this phase of science, in its turn, emerged from the general reaction that the young mind

[1] This paper treats of the work of young children, and is thus not strictly within the scope of a book dealing with secondary education; but such early work well done makes so much difference to the attitude towards science later on, that no apology is made for including it. For references to similar work at a later stage, cf. Mr. Latter's paper on Biology.—ED.

shows to the stimulus of its natural environment. Although nature-study means the study of nature generally, yet in its more restricted and technical sense it must be associated with the early phase in the evolution of the scientific interest, and must concern itself with aims, scope, and methods that are in tune with those particular mental conditions. It is therefore essential for any teacher of nature-study that he focus his attention both on the general attitude of the normal child towards his surroundings, and upon any records of the conduct of primitive man to whom the world, too, is "so new and all."

Interest in the natural environment and objective existence generally is invariably present, and from an attitude of attention and a state of interest there arise the more definite mental states of wonder and curiosity in response to influence of the outer world. This vague state of wonder contains elements of awe, fear, admiration, and other emotions all blended together in an "ah!" state, from which any one may become more definitely differentiated and predominant. Similarly in that monkeyish curiosity we see a seed that will give rise to the most varied forms of intellectual activity. Even at an early stage it expresses itself in the tendency to investigate everything and to a general destructiveness. The investigations are generally spontaneous reactions to the new and strange that

often claims quite involuntary attention. They are fitful and superficial, and any conclusions that may be arrived at tend to be illogical.

The most characteristic feature of these hasty conclusions and interpretations of the observations made is, that they are the result of reading man and his ways into all natural phenomena. At the time that a child enters upon school life he is still at this animistic stage, and his tendency to personify all processes and objects of nature finds its parallel in the myths and legends of the young human race.

The characteristics, therefore, that are most prominent in a normal child and that directly concern nature-study are—

1. Intense interest in the objective world, especially in all living things, and desire to investigate and to understand.

2. Great mental and bodily activity and alertness and incapacity for prolonged concentration.

3. Vivid imagination and strong emotion, which often lead to hasty conclusion and interpretation on the one hand, and creativeness and inventiveness on the other.

The foregoing are definite data which must never be lost sight of in determining the selection of our material for study and our method of approach. It must further be borne in mind that the child is changing, passing from a fitful

and often emotional attitude towards the world of nature to a stage of more purely intellectual interest and greater concentration; and that therefore only a scheme of work which is progressive both as regards subject-matter and method can be considered as vital and organic.

Since nature-study is essentially a particular attitude of mind, which generates a particular method of approach, it is absolutely unrestricted in its choice of material for study. In fact, as it represents the reaction of a young mind to the direct and immediate influence of an unexplored but a priori interesting environment, the more clearly the latter is shown as a complete whole, untouched by the analysis and generalisation of scientific thought, the more perfectly will the conditions of nature-study be fulfilled both in letter and spirit.

The practice of choosing for a course of lessons objects of nature which belong to the same class, e.g. rodents, insects, composite flowers, cannot be condemned too strongly. The very fact that we have a class or group shows that analysis and selection within the realm of nature has already been made, and generalisation and classification has followed, leaving the children to ruminate instead of to browse at their liking. We speak so fluently in educational discussions of the need of passing from the particular and

individual to the general and to classification, but again and again we find the ground all suitably prepared that should be virgin soil for the children.

It is, nevertheless, true that the topics in a scheme of study should be connected, but it is not logical connection that is the desirable. Far better results are obtained if the subjects are psychologically connected in experience, that is, if those threads in the web of nature that bear definite relation to one another are presented in close connection, so that by thought association the picture of the whole will remain intact. Thus, lessons on a particular pond, including the study of the conditions that prevail there, as well as of its inhabitants, would make a suitable series, as long as we do not consider the subject under the following headings: (*a*) Physical conditions, (*b*) Plant life, (*c*) Animal life; this would again imply premature classification. Another profitable course can be constructed on an *imaginary* walk through a lane in autumn, when coloured and falling leaves, ripe hips and haws, deserted nests, gossamer, toadstools, etc., might be studied in detail, as they are met with in actual experience or during an imaginary expedition. No difficulty will be experienced in selecting many courses of lessons arranged on this plan. This is specially true of classes in country districts, where direct experience of the

region as a whole at any particular time can be supplied or depended upon; but even in cities abundance of material is available which in its setting does not entirely transcend the children's own experience.

It stands to reason, that the seasonal aspects of nature will be strongly emphasised throughout, not only because the appearance of things is "just so" because of the particular season, not only because it is easier and cheaper to obtain specimens that are in season, but very specially because our own mental and physical conditions vary with the seasons and we are naturally more sympathetically inclined towards things that sound the same elemental note.

These, then, seem to be absolutely essential factors in nature-study, viz. that it precedes analysis and specialisation and is unrestricted in its selection of material; and that it invariably deals with actual material leading to direct sense experience.

The question may be asked, how can work be made progressive, if we cannot reserve certain material for junior forms and other material for older pupils? It is on the whole preferable to lead the children every year to "fresh woods and pastures new," yet this is not done because the study of one creature and its ways is necessarily more difficult than another, but simply in order that during their school course their experience

of the world of nature may be as wide as ever possible. Under certain circumstances, however, as for instance in the case of the nature-study in our crowded and poorer city schools, it is often necessary to study some one or more of its subjects during several consecutive years. Since advance in nature-study does not primarily depend on wealth of material, it is incumbent on every teacher to ensure progress in method, and the ideal state of things is reached when the method of teaching is so vital that it gradually changes with the claims of the changing mental condition of the pupil and opportunities are such that ever fresh concrete material can be presented—then there is at once intensity of study and breadth of outlook.

A few suggestions indicating roughly how the point of view and consequently method of approach may be changed as the children grow older may be worth considering. They are based chiefly on some fundamental facts of developing childhood, and imply three stages, which are, however, in no way definitely separated from each other: on the contrary, elements of all three stages are noticeable throughout the years of childhood, but at different periods of growth different elements are predominant.

STAGE I (AGE 7 AND UNDER).

This is characterised by a general interest, a great curiosity in the outside world, chiefly in fellow-beings—in animals rather than in plants. The interest is not so much centred upon the appearance as upon the activity of other creatures—especially such activity as has an obvious parallel in the child's own life. This may be called the "making acquaintance stage"—new individual things are received into the circle of experience and are ever afterwards acquaintances. The children should therefore have unlimited opportunity of watching creatures under normal conditions—frogs, newts, and all the vast number of pond animals in springtime, chickens, butterflies, bees, ants, rabbits, mice, later caterpillars, wasps, earwigs, and birds in the autumn, snails, earthworms, and sleeping creatures in the still white time of winter. Besides animals the children should see at different times the running stream, a pond, and the big sea. They might be taken out in a strong wind and might attend to all details of a heavy shower and a thunderstorm, and the effect of both. At all times the weather is interesting, and, at a time when writing means too much conscious effort, very satisfactory nature charts may be constructed by little children representing the "kind of weather" graphically by colours instead of words; the

meaning of each colour being definitely fixed by common consent. In a parallel column objects of nature, studied at the particular time, may be represented in mass and in colour. These charts, which may be extended by older pupils making them more complex and more accurate, are for the children a most attractive form of representing the pageant of the seasons, being at once a demonstration and a record of facts and relationships.

Throughout this elementary work the children simply watch and express their impression informally either to the teacher or to each other, if the class is small. Feeding the animals is always an interesting occupation, and children's lessons and animals' meals should coincide in time wherever possible. Similarly preparing homes for animals kept temporarily in captivity is an extremely useful occupation, and quite possible with small classes. The plan of directing the children's observation by a constant shower of questions which would cover the ground systematically is out of place—the children's way is not our way, and they lead in this work.

Any expression of judgment and interpretation, any expression of emotion, should be perfectly spontaneous and free, and if a certain amount of definiteness is to be aimed at, brush-work and drawing generally would afford the most suitable opportunity.

STAGE II (AGE 8 AND 9).

This stage is characterised by excessive motor energy. It is essentially the age at which the love of the chase burns, when caps are thrown after any and every butterfly, when heads of flowers are knocked off with a stick, when animals are worried and teased, when a system of drainage is constructed in the garden path after a heavy shower, during which occupation you dig "till you gently perspire." These deeds may refer specially to boys, but the girls' ways are not essentially different, they too clamour for occupation, though it may be in other directions.

Here every form of study, especially nature-study, should involve much manual work. If a topic of interest presents itself, everything that wants making and doing should be made and done. The following are some illustrative specimens of courses satisfying these conditions:—

The City Child's Garden.

1. Making a small wooden box or mending up and strengthening an old cigar-box.

2. Painting the box in some colour selected by each child.

3. Drawing initials in capital letters and preparing a stencil.

4. Stencilling the initials on front of box.

5. Preparing soil to fill the box—putting out stones, etc.

6. Setting sweet peas and sowing Virginian stock.

7. Thinning Virginian stock.

8. Manuring (Clay's fertiliser, mixed with water, being administered with a teaspoon).

9. Making trellis-work for peas, fastening this to box with wire, the holes being bored with red-hot knitting-needles.

10. Binding up the peas with bast.

Needless to say, careful observations are made on the plants throughout.

Every Boy's Aquarium.

Jam jars (glass) are cleaned, string is tied round the top in a particular way. Sand is washed; weeds are attached to stones and the aquarium is fitted out. Tadpoles are put in; implements are made of hair-pins for feeding them; caddis-worms are supplied, and experiments are made with different materials with which they might build their home. This work can be continued throughout the term.

Similarly breeding-cases can be made for caterpillars and the life history of the latter studied.

STAGE III (AGE 10-12).

Curiosity, which has so far led to mere sense perception, is now passing into a desire to investigate in order to interpret and to understand. The work is becoming more intensive. It consists of the more detailed investigation of certain more or less isolated topics whose sequence is determined by the march of the seasons. The following are some typical examples:—

As spring approaches man's thought is turned towards the sowing of seed. This is done according to tradition, seeds being put into the ground and watered and sheltered; and seedlings are expected to appear after a certain time. The children wonder what the seeds do in the ground before "they come up," and they are invited to peep into the ground and look. This means disturbance—could the seed be put into something else where the whole of it may be seen. This leads to the question whether soil is necessary. Since one element of traditional procedure has thus been critically examined, the remaining ones are certain to be investigated also. Is water necessary for growing seeds? What about light, warmth, and air? What effect has the absence or presence of these factors? All these questions lead to a long series of simple experiments, involving the construction of apparatus, planning out special contrivances in order to test conclu-

sions, and throughout the children learn to watch patiently, to think independently, and to form conclusions which are truth to them, inasmuch as such conclusions satisfy all the claims which the children will make on them. A similar series of experiences and activities is involved in the potting of a bulb by each child. It is interesting to notice how the significance may here be established of mathematical work, which is attempted much later. As the shoot appears above ground, it is accurately measured with a strip of paper and the distance between the two dots is marked off vertically on a sheet of drawing-paper, and the drawing of the shoot is made in colour between the two dots. This is repeated at equal periods of time on the same sheet of paper, and it is easy to see how graphs relating to rate of growth can be constructed from this. Thus, too, in the study of the snail when investigations are being made on the manner and rate of crawling, the children can measure the slimy track of a snail made in one or two minutes, by means of a piece of cotton and a ruler, and represent the exact number of inches by an upright line; the distance crawled over in any subsequent two minutes is similarly represented by vertical lines that are equidistant and drawn from the same horizontal lines. The rate of crawl may thus be graphically represented, and any variations due to fatigue, perception of food, etc., at once detected.

The whole of this stage is characterised by the pursuit of a definite line of investigation, by more cautious judgment, and by more exact record.

Space does not permit to deal with the component elements of any one lesson, but it cannot be emphasised too strongly that the greatest freedom and absence of all formal instruction, in the case of young children at least, should be allowed wherever school conditions, such as great size of class or overcrowded rooms, do not impose restrictions.

Gardening and rambles are the most powerful aids for promoting efficient and healthful nature-study, and the time is not far when these pursuits will form an integral and organic part of our school work.

IV

BIOLOGY IN SCHOOLS

By OSWALD LATTER, M.A.

THE position of biology among the natural sciences which find a place in school curricula is rather peculiar. An enquiry recently made under the auspices of the British Association made it clear that in a large number of schools the introduction to science consists of "nature-study," of which a large portion is biological in character; but it was also evident that very few schools pursue biological study any further; and in the majority of those that do so the subject is confessedly confined to those pupils who are hoping to enter the medical profession. The sub-committee appointed by the British Association, in their report presented at Dublin, express regret that biology is not more widely taught in the upper forms of schools. There is thus no doubt that the merits of zoology and botany as subjects of general education are not generally recognised; such higher work as is done in schools is usually but the preliminary course of the future doctor,

and is therefore "technical training" applied to a few only.

If we search for the causes of this apparent aversion from, or at any rate avoidance of biology, dearth of teachers seems to be the chief. The number of men who take the Final Honour School of Zoology or of Botany at Oxford is very small, and probably because these subjects do not appear to offer any livelihood. The School of Forestry, no doubt, will lead to an increase in the botanical students at Oxford, but these men are already "ear-marked," and of no account in the present question. Similarly at Cambridge, where at least three subjects are demanded for Part I of the Natural Science Tripos, although considerable numbers offer zoology and botany, the majority do so for purposes of medicine. But if schools were to widen the ground of their science teaching and adopt biology as a regular general subject, there would be an inducement to men who are interested in the study of animals and plants to take up zoology and botany for their degrees with the direct intention of teaching and thereby gaining their living. At present we seem to be moving, or more accurately, standing still, in a vicious circle—biology is not taught because there are no teachers; there are no teachers because biology is not taught.

With the rival sciences of chemistry and

physics it is far different. The £ s. d. value of these subjects is evident, and the openings of careers plentiful; there is no dearth of excellent and devoted teachers. Lest there be any misunderstanding, it will be prudent at once to admit that for training in experiment, in methods of precision, and in exact reasoning physics and chemistry undoubtedly have the advantage over biology, but they do not equal biology in quickening the powers of observation, and it is, at any rate, open to question whether they are as truly suitable for *general* education. A great portion of the strength of their present position in education is derived from the appreciation of their utilitarian value by the British Public. The market price of the study of insects and snails, of fishes and crustaceans, of trees and fungi, is not yet appreciated, but may possibly be realised to some extent by the mention of the tsetse fly and *Anopheles* gnat (both of imperial importance), the ravages of the liver-fluke among sheep after it has left its intermediate (snail) host, the work of the Marine Biological Association in husbanding the harvest of the seas, the improvement of cereals and other food plants, thanks to the researches of biologists into the laws of heredity, the life-history of wheat-rust and other harmful fungi—to name only a few of the peculiarly valuable discoveries by which almost every one of us is directly or indirectly benefited.

It is difficult to understand the reluctance to teach biology in face of the fact that this science is concerned with phenomena and problems which meet us everywhere in our daily life both in the world around us and within our own persons. Moreover, it offers exceptional opportunities for the stimulation of the power of independent inquiry and direct observation on the part of the children themselves; and that on occasions other than those of attendance in the classroom or laboratory, viz. in the play-hours and during walks in the country or the town, and abundantly during holidays. To many it may well become an intellectual hobby, something on which the mind will exert itself for the mere love of it. Is any further justification of the place of biology in education necessary?

Turning now to the actual practice of teaching, it is natural to enquire at what age biology may be introduced. Every one who has had to do with quite young children, especially those who are fortunate enough to have their homes in the country, must have noticed how great are the attractions of living animals and plants even to mere infants—their pets and their gardens have an absorbing interest and are tended with a care and keenness that is truly refreshing. We need then have no hesitation in making a beginning very early, indeed almost before the days of regular schooling are reached. It will be a step

forward to get the children to notice their plants and animals a little more carefully; to write short descriptions of them and perhaps compare them with one another, and thus gain some conception of the external form and structure of living things. A very useful and instructive bit of work would be found in the descriptions and comparisons one with another of, say, a rabbit, a canary, a tortoise, a toad, and a goldfish; or again, tulips, geraniums, wallflowers, mustard and cress, or whatever plants were receiving attention in the small garden, might be used in a similar manner. It is certainly important to press home at an early stage the idea that plants are living things, and that all living things which are not plants are animals. It is curious how often one has to eradicate the idea that birds, fishes, insects, etc. etc., are not animals; there is a widespread misconception which would define "animal" as equivalent to "mammal," and which even then indignantly repudiates the suggestion that Man is an animal. There is a great gain in sympathy if it be realised that our life is very much the same in essence as that of other living things, and that we and they are all knit together in one great and mysterious bond, the riddle of whose forging has tasked and is tasking some of the keenest intellects, and is yet unsolved.

Occasionally one comes across a child to whom such descriptive and comparative work as that

just suggested is easy and spontaneous; more commonly guidance is necessary in order to prevent discursive muddle and to initiate orderly method. Such guidance is best given by a series of questions; for example—"How many limbs has each of these animals? How do the limbs of the rabbit differ from those of the canary and of the goldfish? What sort of covering has each of these animals?" and so on. A risk involved in this method is that of receiving in writing answers which are permissible vivâ voce. A complete sentence should always be insisted on; the habit thus formed is invaluable. For instance, to the first of the above questions the answer "Four," should be refused, and the complete sentence, "The rabbit, the canary, the tortoise, the toad, and the goldfish each have four limbs," should be required. A little later, and with some practice, we may ask for consecutive and connected sentences descriptive of the objects in hand, and then the value of the insistence on well-composed sentences is quickly appreciated. At an almost equally early age attention may be directed to "phenological" phenomena. The arrival of swallow, martin, cuckoo, and other common spring migrants, the opening of leaves and flowers, the first flights of bees and wasps are eagerly looked for, and the notice of these conspicuous appearances, in addition to adding greatly to the delight and interest in living nature,

lays the foundation for life of the seeing eye and hearing ear.

With pupils of public-school age we may proceed to more serious work and pass on to enquiries into the life, habits, and functions of animals and plants. How does each one get its food? Of what does its food consist? How does it breathe, how move (if animal)? In what sort of place and surroundings does it prefer to live? What kind of home or nest does it (the animal) construct? How does it find a mate? In what condition are the young produced? Do they receive parental attention after birth, and for how long? Are the adult animals solitary or gregarious or even social, and, if the last, what duties are performed *pro bono publico* within the society to which they belong? A host of other questions will readily occur to any teacher, appropriate, *mutatis mutandis*, to zoological or to botanical research of this kind. Too much stress cannot be laid upon the maxim of not telling anything that the pupil ought to be able to make out for him- or herself; nor should the necessity of insisting on drawing freehand illustrations from the object under observation be overlooked. Every one can learn to draw sufficiently well to find the accomplishment useful, though, of course, artists cannot be made any more than poets.

In selecting material for work of this kind the

teacher will be guided more or less by the locality of his school; but in any case it is the common everyday animal and plant that should receive the closest study. Worms, snails, oysters, or mussels, insects of many kinds, fish, frogs, and toads are not difficult to procure nor to study alive at any inland school; while at the seaside the fauna of shore-pools and fishermen's nets will afford more than enough for a year's course. Similarly in the plant kingdom, mosses, fungi, lichens, and moulds are of universal occurrence, and can be studied profitably without having recourse to the compound microscope; nor should there be any obstacle to prevent the dissection of flowers, the study of leaf-form, of stems and their modifications, and of the general characters of plants adapted to special circumstances. If a school-garden exists, small plots can at comparatively little cost, especially if the pupils are (as they should be) the actual tillers of the soil, be laid out as (1) a pond, (2) a marsh, (3) a salt-swamp, (4) a dry sandy heath; and here may be studied the peculiarities of hydrophytes, halophytes, xerophytes, and the rest, but not under these titles except in the mind of the teacher. A really valuable and much-needed bit of work consists in the study of the germination and early stages of common weeds. We are not aware of any book in which the facts relating to these are given. Sets of pupils might be

assigned to look after about half a dozen species each, to keep records of their behaviour and make sketches and photographs at frequent intervals. Each task may be considered complete when seed has been obtained from the plant which developed from the seed sown.

Research of much the same character is possible among animals. The life-histories of a large number of our commonest insects are but imperfectly known, and probably any one of them if carefully observed would yield facts new to science. Or, again, the immature stages and plumage of many common birds have as yet received very inadequate treatment. But whether the knowledge obtained is new to science or not matters very little; it is new to the pupil, and it has been gained by his own efforts and observation. He has learnt that he can learn, and probably that he likes and wishes to learn.

At about this period it is well to devote some time to function—to introduce a course of elementary physiology, making it as experimental as possible. Human physiology is undoubtedly the best; children have learnt incidentally that they have muscles and use them to produce movement; they know that they breathe, and that under certain circumstances they breathe more rapidly, and that certain appearances result if they "hold their breath," or if they constrict a finger with a bit of string so as to impede the

free circulation of blood; they are aware that they need fresh air, and get headaches if compelled to sit in stuffy rooms; they realise the importance of food, but do not always feed wisely, nor allow their digestive organs the rest that health demands. They are thus ready for a general knowledge of the structure and working of the human body and its several organs, and *en route*, may receive the very necessary information on personal hygiene that should be possessed by every one. This course will here and there, e.g. in dealing with the blood, involve the mention of cell-structure, and will open the door to the more systematic study of zoology and botany, which can be undertaken at the age of about sixteen or seventeen years.

By this time, either in the physiological course just suggested, or in the other laboratories, some knowledge of chemistry and of physics will have been acquired; and the systematic biology may advantageously be run on frankly evolutionary lines. The compound microscope is now a necessity; hitherto the simple lens will have sufficed. Opinions differ as to the advisability of beginning with the unicellular organisms. Huxley was in favour of using the frog as an introductory type, and others whose position and experience render their decision weighty advocate the same course to-day. I venture, however, to think that after a short course in the

essentials of human physiology pupils are in a position to appreciate the generalised structure and absence of division of labour in the lowest forms of life, and can readily grasp the importance of the higher forms as they proceed step by step along the course of life as indicated by existing creatures. The kind of plan which is in view is that admirably exampled in Jeffrey Parker's *Elementary Biology*, to mention but one of several good books suitable to this stage. In this, the last, portion of a school course, clear ideas must be gained of the chief types of animal and vegetable architecture, principles of classification should become familiar, and some idea of the meaning of the words "genus" and "species" obtained. Excellent studies in specific differences can be found in the social wasps among animals and in the wild poppies among plants. Lectures and reading assume importance at this period, for such subjects as embryology, geographical and geological distribution, heredity and variation, and other problems in biological philosophy are not now beyond the reach of intelligent pupils. Chapters in the *Origin of Species*, and perhaps the whole of Wallace's *Darwinism* and of Punnett's *Mendelism* ought to be read and discussed.

Space does not permit full treatment of the part to be played by the school museum in the teaching of biology. The collection should

contain well-displayed and fully-described specimens of the chief forms of animal and vegetable life, especial prominence being given to those which are of common occurrence in the neighbourhood. No doubt it will be found necessary to purchase some specimens, but the educational value of the collections and the general interest in them will be greatly enhanced if the majority of the preparations are set up by the pupils themselves. It should be an honour to do a piece of work sufficiently good to merit preservation. The museum, properly handled, should be a means of preventing the production of mere laboratory biologists—a product that is too frequent. An examiner for a biological scholarship recently set as a question in the "practical" paper a number of specimens gathered partly during a walk along the seashore and partly during a stroll round his garden; the specimens were all of common occurrence, but proved themselves the hardest part of the whole examination to all the candidates. Biology cannot be considered as satisfactorily taught if it fails to excite an interest in the life that meets our eyes in our daily walks.

V

THE TEACHING OF HYGIENE

By ALICE RAVENHILL

A DEFINITION of education which commends itself for the purpose of this paper describes it as "the process which aims at the adjustment of the growing organism to his environment," incidental instruction being directed to the child's equipment with the knowledge necessary to give him control over conditions by understanding them. For this purpose the record of human experience is presented to the pupil in the form of history and geography; lessons in language and literature illustrate the growth and development of mind and manners; while, by the aid of elementary science teaching, the law of cause and effect in the realm of nature is practically demonstrated to his inexperience. But, as the result probably of the prolonged and artificial isolation of man from his biological connections and of the contempt of the body associated with certain phases of religious and ethical teaching, the obligation to acquire knowledge and to train powers, with

the direct object, not of intellectual but of physical culture, has but recently suggested itself to the world of educators. Charlemagne, however, seems to have been alive to the fact, for, in his edict on the establishment of schools, he writes that "Though right doing is preferable to right thinking, yet must A KNOWLEDGE OF WHAT IS RIGHT PRECEDE RIGHT ACTION." But public opinion was not ripe for the recognition of this truth, or, at any rate, for its application to the care of the body, so that, after a lapse of eleven hundred years, it is still necessary to point out that empiricism and ignorance must be banished from this as from other spheres of human activity, and the youth of the country trained to the realisation that in hygiene is found the sum of scientific knowledge directly serviceable for the right conduct and beautifying of human life.

That the Board of Education is in sympathy with the importance of cultivating a sense of personal responsibility for the lives we have and the health we might have is suggested by several passages in the Regulations for both Elementary and Secondary Schools, which set out the desirability of forging links between lessons and life, by training in accurate use of thought, in practical ability to deal with the affairs of life, and by exercise, physical as well as mental. Certain difficulties arise, however, when considering: (1) the position of the subject in the school pro-

gramme; (2) the methods by which it should be presented to pupils of different ages; (3) the preparation of the teacher for this work.

I. THE POSITION OF HYGIENE IN THE SCHOOL PROGRAMME.

This will entirely depend upon whether the Direct or Indirect Method of Instruction is adopted. At the present moment a majority of teachers favour reliance upon the general atmosphere of hygienic observances, which surrounds the pupils in most schools, as the best means of training in good habits and in the assimilation of sanitary precepts; but this method has the grave objection that any theoretical basis for action is usually incomplete, disjointed, restricted in scope, and often quite perfunctory. Consequently, though good personal habits are formed, the power of facile individual adaptation to unfamiliar conditions is wanting or weak.

Exception to the Direct Method of Instruction is usually taken on three counts: (1) that it often fails to interest healthy-minded boys and girls and may develop morbidity in the debilitated or introspective; (2) that demands on time forbid the introduction of any new subject; (3) that hygiene is deficient in educational value and useless for examination purposes.

The first objection is based largely upon what appears to me to be a misconception of the

methods with which it should be associated; for instance, so much stress has been hitherto laid on the negative rather than on the positive in human health, upon the abnormal rather than upon the normal in human life. I think too that psychologically the child from ten to fourteen or fifteen is not ripe for a detailed study of the principles of hygiene, and consider direct instruction can be advantageously reserved till the last few months of school life. Where the pupil passes on to college, further postponement is permissible. With the second objection I am in full sympathy. In respect of the third, the great value of hygiene as a lens by which to focus learning on life has yet to be generally realised. Personally, I would like to see Hygiene an optional subject in School Leaving, Higher Local, Matriculation, and equivalent examinations.

Reflections on the reason why a study of right living fails to interest lead on to a study of the methods by which it should be presented to pupils. Hitherto, the subject has been too often actually introduced by a study of "dry bones"; has been restricted to its personal and domestic aspects, in which the boy and girl have little interest; and has been devitalised by isolation from its relation to almost every event in life and to every subject in the curriculum. It has been conventional to teach hygiene as a compendium of scientific theories or of statistical facts, instead of con-

centrating attention on the significance of the doings of daily life—so familiar as to be usually unconsidered—and by tracing these back to their hygienic origins or onwards to their protective results on the public, utilising them to cultivate a scientific habit of mind and a sense of civic duty.

The provision for the preparation of teachers for this branch of their work too has been so imperfect, that they have been placed at a serious disadvantage when called upon to handle it in schools.

The words of an old writer on the education of youth aptly embody the guiding principle to be pursued by the teacher who desires to make hygiene at once attractive and productive. "That which is to become a power in the pupils," he writes, "and to be closely welded to his most cherished thoughts and feelings must not pass hurriedly and unconnectedly before his soul like the images of the kaleidoscope; it must occupy him long and uninterruptedly." Instruction should therefore be continuous; progressively adapted to phases of growth and interest; observational and concrete in method; varied and elastic in application; correlated with the humanities, with science and with art; preferably intensive for a short period on the threshold of emancipation from tutors and governors, to prepare the youth for the responsibilities of manhood and citizenship, the maiden for womanhood and the wise direction or performance of domestic duties.

II. METHODS OF TEACHING HYGIENE.

It will be assumed in the following suggestions that advantage has been taken of the little child's imitative, dramatic, and constructive instincts to lay a firm foundation of good habits. The love of doing and of repetition, the impulses to activity and investigation, facilitate the organisation of bands of little doers in nursery, infant school, and kindergarten, whose training in personal niceties and in social consideration will form life-long hygienic habits. It will be further assumed that in preparatory and elementary schools the child's quick observation and keen curiosity have been utilised, as has been so admirably suggested by Miss Hoskyns Abrahall :[1] (1) to observe facts in nature; (2) to draw conclusions from these facts; (3) to apply these facts to daily life. She has pointed out, for instance, on more than one occasion, the mass of hygienic inferences which may be associated with the careful observation of a green, flowering plant; its general characteristics and requirements; its dependence on air, sun-light, and food; the influence of its environment (cold, heat, drought, damp, darkness, soil, etc.); the results of overcrowding; the presence of para-sites. By this means intelligent interest is de-

[1] "The Correlation of Hygiene with other subjects in the School Curriculum." *Transactions Royal Sanitary Institute*, Vol. XXV, 1905.

veloped in the various devices of living organisms for the maintenance of life; the process of circulation, for example, or respiration, of assimilation, excretion, growth, and reproduction, the machinery for which becomes more highly differentiated as animals ascend the ladder of life, until man is reached on the topmost rung. To describe this method of inculcating the elements of hygiene as "biological" savours, perhaps, of the high-flown and the superficial; nevertheless, with certain reservations, it is accurate.

Thus prepared, the boy or girl is ready to pass on to that method of teaching hygiene, the *Correlational*, which seems more appropriate in the secondary school; for, while making no increased demands on precious time, it nevertheless vivifies and illuminates every subject in the curriculum, cultivates the dawning powers of reason, develops ability to apply information, and trains at one and the same moment in appreciation that problems exist and of the means adopted for their solution. In geography and history, for instance, the effects on human development of climate, of soil, of food-stuffs, of water supply or of indigenous diseases may be traced. The influences of local conditions on industries, nutrition, customs, civilisation, social progress and position among the races of mankind will emphasise the fact that civilisation and sanitary science are most intimately related; that, according to the character

of the artificial climate with which man surrounds himself in clothing and home, according to the attention he gives to the disposal of refuse or to the due supply of wholesome food, according to his restrained and intelligent utilisation of his instincts—personal and racial—will be regulated not merely his own personal efficiency and civic worth, but the position of his people among the great powers of the world.

In the science laboratory the perception of the fact that all energy dispensed is the result of chemical reactions can be so turned to account as to open young students' eyes to recognise what Professor Sherrington has pointed out, that "the body's material commerce with the world is chemical"; a new light will thus be thrown upon the chemistry of respiration, of metabolism, of fatigue, and of other functional processes. In the course of a study of elementary physics, illustrations may be drawn from the heart as a force pump; from the eye as an optical instrument; from the structure of the ear as an instrument for the process of sound transmission. The employment of the thermometer and barometer for man's guidance and well-being; the application of the principles of the siphon to domestic and municipal purposes; the analogy between the liberation of nervous energy and an electric discharge, for instance, may all be turned to profitable and practical account in this correlational method of

teaching hygiene. Again, an insight into the mechanics of the body in relation to posture often awakens a genuine interest in physical culture, and the routine occupations of daily life assume new and more interesting aspects when articles such as milk, soap, lemon-juice, or washing-soda are used to illustrate the characteristics of emulsions, acids, alkalies, etc., in the chemical laboratory, or the organic nature of much domestic dust is demonstrated by bacteriological methods. Much incidental instruction in hygiene is given to girls in some of the admirable courses in the Domestic Arts closely correlated with the science work, carried on in a growing number of secondary schools; but as yet they concentrate somewhat too closely on the purely personal and domestic aspects of the mother subject. Advantage is also generally taken of the physical-training classes in girls' schools to associate the exercises with some of the reasons which render them desirable, and to direct attention to the effects by which exercises are attended—bodily warmth, for instance, hunger, thirst, or fatigue; the importance of adequate ventilation and of suitable dress being kept carefully in view. In a few boys' schools I believe that similar lines have been adopted, but they could well be extended.

The recent movement in favour of more organised training in social as well as individual

morality prepares the ground also not only for an introduction to civic duties in respect of sanitation, but for some preliminary initiation into the economics of health, as reflected in the utilisation of time, energy, strength, and money, with a due regard to personal efficiency and racial responsibility. The application of art to sanitary science can also be suggested, and in some cases considerably elaborated; though any tendency to supersede the educational by the technical needs careful supervision and maybe repression.

A second method of teaching hygiene in secondary schools can be most fitly described as *Superstructural*, because, as has been already suggested, it is most profitably adopted during the last months at school, when it should be presented as one channel of most practical application to human needs of human knowledge, and should have devoted to it at least two and preferably four hours a week. As a necessary preliminary to what should consist of a short study of human life and its requirements, some general outline must be given of man's place in nature, accompanied by a brief résumé of the biological laws which reign in the world of life. Much of this will be already familiar to pupils whose early study of nature has been pursued in the form of elementary botany or zoology; but at this point more stress than hitherto will be laid

on the relative importance to MANKIND of inheritance or environment, of nutrition or stimulus; while the meaning of diathesis and the worth of adaptability and of power to control conditions must be explained. The interconnection of growth, nutrition, and stimulus; the time law in living matter, which makes of such importance the right regulation of physiological rhythms and their cultivation as habits; the maintenance of individual immunity to disease—chronic and acute; the ethical, industrial, and social aspects of hygiene, all call for review and emphasis, in proportion to the development, special needs, and probable future positions of the young people immediately concerned.

When human life is thus studied in relation to organic and inorganic nature, it will be observed that its activities resolve themselves into two large groups—one of which is concerned with care for self (food, shelter, environment), the other with care for others (the young, the helpless, neighbours, relatives, and fellow-countrymen), thus covering the whole sphere of human existence. The introductory matter of this course might well be identical for boys and girls, for the outlines of human physiology and of personal hygiene should be common knowledge; but as the course proceeds, divergence becomes obligatory, in view of the varied duties and functions of man and woman. The lines of this diver-

gence can be most concisely illustrated in tabular form thus :—

GIRLS.	BOYS.
FOOD.	
Retail cost. Domestic care and storage. Preparation, cooking, and serving. Dietaries for various ages.	Cost and method— of production. of distribution. of preservation and storage. Legal protection.
DOMESTIC HYGIENE.	
Details of choice and care of houses and institutions. Cleansing methods. Furniture. Decoration. Household economics (financial and hygienic).	House planning, construction, and repairs. Water supply. Methods of refuse removal. Lighting, warming, etc.
ECONOMICS OF HEALTH.	
Care and education of infants and children. Occupations. Domestic service. Maintenance of personal efficiency. Racial responsibility.	Civic duties { Sanitary. Educational, etc. Industrial occupations. Maintenance of personal efficiency. Racial responsibility.

Neither the suggestions for this short course of intensive study of hygiene nor those given at an earlier point in this chapter assume to be more than general indications of methods shown by experience to be reliable and feasible. Within the assigned limits of space it is only possible to indicate in very general terms the means by which this indispensable instruction can be utilised to quicken the sanitary conscience in the adolescent; to broaden the intellectual horizon; to raise and strengthen ethical ideals; to awaken a sense of social responsibility; to become, indeed, for boys and girls alike, a great humanistic study.

But at no time in the history of our country has it been of greater moment to open the eyes of our young people to the fact that each generation "owes it to itself and to its posterity to protect life, to enrich it, and to transmit it, elevated and refined, to succeeding generations." Thus the obligation to fulfil this duty can no longer be ignored by those who have assumed responsibility for the education of youth; perhaps especially so in the case of those who, in the near future, will exercise much influence in the affairs of men. When hygiene is defined as "a study of the means at our disposal for the right conduct and transmission of life," its educational worth and the strength of its claims on the attention of teachers admit surely of no more question, of no more hesitation on the part of

those who control subjects and curricula in schools; rather the difficulty lies in the choice of method and in the details of its elaboration.

III. THE PREPARATION OF THE TEACHER.

Very brief reference only can be made to this element in the successful teaching of hygiene; though when the claims made on teachers, by the methods advocated, are considered, its importance cannot be overlooked. The provision made at present to meet these demands is quite insufficient for those working in secondary schools, more especially for men teachers. At two or three training-colleges, at Bedford College for Women, in the Women's Department of King's College, courses of varying length are now available, but mostly at the cost of at least one year's post-graduate work, in addition to all the other demands on a teacher's time and purse. The University of Liverpool also offers, I believe, a better opportunity than elsewhere to male students of education for gaining insight into the "biological study of hygiene," but even this course falls far short of the requirements sketched out by Professor Sherrington at the Conference on School Hygiene held in London by the Royal Sanitary Institute in 1905.[1] To discuss these

[1] "Training in Hygiene for Teachers," Professor C. Sherrington, *Transactions Royal Sanitary Institute*, Vol. XXV, 1905.

requirements, and the revision of Degree or Training Courses necessary to comply with them, is outside the terms of my reference. To mention them, as most intimately associated with the education of children in the principles and practice of hygiene, is a duty owed to those boys and girls who look to us to fit them to utilise, as increased opportunities for noble living, the rich resources of twentieth-century civilisation.

VI

THE PLACE OF HYPOTHESES IN SCIENCE TEACHING

By T. PERCY NUNN, M.A., D.Sc.

IT is related of Sir William Hamilton (the mathematician) that he was once saluted in the street by a non-scientific friend who had just come from a place where the elect were comparing impressions of his newly published *magnum opus*. Buttonholing the great man, the friend expressed in warm terms both his congratulations and his sense of the happiness of the meeting; "for," said he, "I happen to have three minutes to spare, and you will no doubt be good enough to tell me what *are* Quaternions."

Save that they are not heirs of his own invention that are called in question, the science master is in a position with much the same difficulties as Hamilton's when he is pulled up in class by the Fourth Form boy who wants to know—incidentally—"what *is* electricity?" or "what *is* ether?" The perplexity of the teacher at such a moment will, in fact, be greater the more he has reflected upon the questions so lightly raised;

for he will then know that the answers, if they are to be secured at all, must be sought in a "misty mid region" of controversy and speculation in which a Fourth Form boy would find himself helplessly befogged. His enquiries raise, in fact, the interesting but difficult question of the "import" or logical standing of the hypotheses which play so conspicuous a part in the development of scientific knowledge. In a word, are such entities as ether and electricity (as many think) some of the final, indestructible realities of which the universe is built, or are they (as others maintain) only such stuff as scientists' dreams are made of? To the consideration of this question—a question highly relevant (it will appear) to the daily business of the science teacher—this article is addressed.

In a well-known popular lecture the late Professor Huxley once illustrated with characteristic brilliance the power of "prospective and retrospective prophecy" which is the proudest possession of Science, and with characteristic lucidity identified it with the patient and confident use of one great principle—namely, that like effects imply like causes.[1] In virtue of this principle the astronomer who has shown himself able to predict future celestial occurrences claims that he is able to determine with equal exactness

[1] "On the Method of Zadig," 1880; reprinted in *Science and Culture.*

those that have long been swallowed up in the abysm of time; the physicist believes that by its aid he can assign an approximate limit to the age of the solid earth; while the geologist makes an obvious use of it when he interprets a "fossil" as a relic of ancient life.

Huxley's illustrations are drawn in the main from the sciences of which he was so conspicuous an ornament, but there can be little doubt that he would have included the results of the physical sciences in his catalogue of the intellectual conquests man has won by the aid of the "method of Zadig." The "ether" which to Lord Kelvin was among the most certain of realities; the "energy" which, according to Heaviside, is (with the exception of ether) the only thing that exists, all else being "moonshine"; the "molecules" the details of whose architecture are discussed in every number of our chemical journals; the "ions" whose masses and velocities are catalogued (like populations and death-rates) among our statistical information: all these entities are as inaccessible to direct human observation as the eclipse which Airey retrospectively assigned to the afternoon of May 28, B.C. 585, or the opossum which Cuvier reconstructed from a fossil jawbone; and our conviction of the reality of each and all of them must be regarded as justified only by the principle that like effects imply like causes.

But while it is probable that Huxley, like most scientists in his day, would have been perfectly willing to make these further applications, it should be remarked that throughout the period of development of modern science there have been thinkers of a more cautious disposition. These would agree that it is the peculiar virtue of the scientific mode of treating experience that it enables us with equal confidence to predict experience yet to come or to "reconstruct" the experience of our ancestors; but they would make a more or less clear distinction between the observable phenomena which are really the subject of prospective or retrospective prophecy and the machinery of scientific conceptions by which the prophecy is brought about. With regard to the former, it must be admitted that they were once, or some day will be, as "real" as the facts of which at the present moment my senses are making me cognisant; but with regard to the latter it is possible to recognise their usefulness as the instruments of scientific prophecy and yet to abstain from formulating any opinion with regard to their objective reality.

This attitude was given interesting and quaint expression so long ago as 1635 by our countryman Henry Gellibrand, who, while admitting the value of the Copernican hypothesis "for the more easy solving the apparent anomalar motions of the fixed and erratique caelestiall lights, and

avoiding that supervaconeous furniture of the Ancients,"[1] yet regarded it not as an objective truth, but as a consequence of "the imbecillity of Man's apprehension, as not able rightly to conceive of this admirable opifice of God" in all its actual complexity.

Mach maintains that the great Newton was fully aware that such notions as "central force" are merely apparatus for the intellectual manipulation of facts, and there can be no doubt that this was true in the main of the attitude of Joseph Black towards his "caloric," and of some of the chemists of the early nineteenth century (e.g. Wollaston, Davy, Liebig, Faraday) towards the atomic theory. But the astounding success of the Newtonian mechanics in the region of physics and of the atomic theory in chemistry inevitably brought with it a general abandonment of this cautious attitude, so that it was in effect the initiation of a new era of scientific thought when Kirchhoff made (in 1850) his famous pronouncement that the business of mechanics is not to explore the "causes" supposed to lie at the back of the observed phenomena of material movement, but merely to *describe* completely and in the simplest manner the motions which occur in nature. At a still earlier date Ernst Mach had begun the re-

[1] *A Discourse Mathematicall on the Variation of the Magneticall Needle*, p. 30.

searches which led to the publication in 1883 of his *Science of Mechanics*, a work in which for the first time the history of one of the great bodies of scientific doctrine was subjected to an exhaustive examination which had as its object the determination of the real significance and value of the several conceptions that have emerged in the course of its development. In the later editions of this admirable book Mach has made generous acknowledgment of the help which his cause has gained from the publication in 1892 of Professor Karl Pearson's *Grammar of Science*. To the appearance of this vigorous and well-known work we may attribute, in fact, most of the attention that is now given in this country to these "critical" enquiries into the functions and mode of development of the sciences.

Professor Pearson agrees with Mach that the function of science in every field of its activity is simply to give "economical descriptions" of phenomena; and the whole body of scientific concepts and "laws" is for him merely so much apparatus for "resuming," i.e. summarising briefly and effectively, the routines of the "sense impresses" which constitute the ultimate data of our experience. Professor Pearson has discerned more clearly and accepted more frankly than any other writer the consequences that follow from this view. How far these consequences carry him from the pre-critical position of Huxley is

shown by his contention—which may seem paradoxical even to the emancipated—that the value of the theory of organic evolution lies not in the revelation of a previously unknown "history" of forms of life, but in its power to give unity to our present perceptual experiences of those forms—a value which would be retained intact even if we should discover that the universe as we know it came into being only the day before yesterday!

Since Professor Pearson's trenchant exposition of the "critical" method awakened English scientists from their "dogmatic slumber," they have, to a constantly increasing extent, been influenced by authors (such as Duhem, Poincaré, Ostwald, Hertz, Ward, Driesch) who have explored the several provinces of science from similar points of view. As a result, our leading scientific writers now constantly admit the necessity of defining their attitude on a question which they find it impossible to ignore. Thus on the one hand we have a President of the Chemical Section of the British Association urging that the atomic theory propounded by Dalton "is not founded upon the metaphysical conception of material discontinuity, and is not explained or illuminated by it";[1] while on the other hand we have a distinguished physicist[2] re-

[1] Professor Divers, *Brit. Assoc. Reports*, 1902, p. 558.

[2] Professor Schuster, *Theory of Optics*, 1904; Preface.

garding "with the utmost concern" the growing "evasion school" of scientists who rest content with equations correctly describing the numerical relationship between observable physical phenomena without an attempt to exhibit these phenomena as flowing from "the mechanical properties of the ether."

The science teacher may be pardoned who, seeing how greatly the doctors differ on these difficult questions, seeks to evade the necessity of taking up any attitude towards them. On certain terms he may be allowed to do so. If in imparting instruction in science he is content to regard himself as equipping his pupil with so much intellectual apparatus that will be of direct service in a technical or professional career, then, without doubt, he need not concern himself about the ultimate nature of any particular piece of this apparatus so long as it is convenient and trustworthy. The prospects of the would-be electrical engineer will not obviously be furthered by curious enquiries as to whether electricity is really the "juice" of the workshop or merely a concept valuable as a means of "economical description"; the future chemical manufacturer is not clearly better off if he is brought to suspect that graphical formulæ are merely devices for "resuming routines of perception." But if the teacher lays stress upon the "educational" aspect of his work; if he claims that its chief value is that it gives

a "training in scientific method," then he cannot be absolved from the duty of facing and adopting some answer to the questions which scientific criticism raises. He may reject the destructive conclusions which so many recent thinkers have reached, and may reaffirm the older optimistic views which accepted molecules and ether as genuine realities; but he must wear his optimism with a difference. In the first place, he must not base it on ignorance of the arguments on the other side; and in the second place, he must not force it upon his pupils. It is falsifying the whole conception of a training in scientific method to lead boys and girls to adopt unverified hypotheses as established and final results, or to think they have found ultimate realities where there *may* be only *a priori* assumptions. Further, it may be claimed that at the proper epoch in the pupil's development a little "scepticism of the instrument" of scientific enquiries (to borrow a phrase from Mr. H. G. Wells) is an excellent thing; tending to correct false impressions as to the labour with which the main positions of science have been gained and held, and to give true views of the greatness of the achievements which those positions represent.

The practical application of these principles of intellectual ethics will best be illustrated by discussing a concrete case of considerable importance, namely, the question whether in chemistry

we shall teach the objective reality of "molecules" and "atoms." Whatever conclusion we may reach on this matter, it may be assumed that we all start by recognising that atoms and molecules appear in chemical theory as means of *interpretation* of a certain group of facts concerning the quantitative aspect of chemical change. For this reason almost every teacher would teach his class these facts—the so-called "laws of combination"—before he introduced atoms and molecules by way of "explanation" of them. All will agree, moreover, that the thought of chemical changes as due to the kaleidoscopic combinations of sets of homogeneous atoms has, in addition to its explanatory value, great *heuristic* value: that is, that it is fertile in the suggestion of new problems for investigation. But agreement will go no further. To some the atoms and molecules will appear to have made out a strong claim for recognition as real existents—even as more real than the gross masses of "compounds" whose behaviour they were invoked to explain. Those infected with the critical virus will, on the other hand, maintain that the sole reality of atoms and molecules lies in their existence as ideas in the mind of the thinker, whose theoretical activities they serve by their power of summarising the results of chemical experiments and of suggesting new lines of investigation. It is in view of the fact that no *demonstration* of either of these posi-

tions is obtainable,[1] and that men will adopt one or the other less on rational grounds than as the result of the temperamental differences that make some Liberals and others Conservatives, some Platonists and others Aristotelians; that the ethical problem arises for the teacher. On the one hand, he cannot ask his pupils to accept, upon the basis of a very slight knowledge of phenomena, a view which men whose knowledge covers a vast range reject. On the other hand, he cannot expect the immature mind to adopt with comfort the somewhat Gilbertian attitude of a "permanently provisional" acceptance of atoms and molecules; the pupil will either think real what he makes use of or will not make use of what he does not think real.

These considerations combine to suggest that the introduction of the ordinary concepts of atoms and molecules should be postponed until the pupil is ripe for the critical attitude and has an acquaintance with chemical facts that entitles him to adopt it. As a matter of fact, there is in the earlier stages of an experimental course no difficulty in giving "economical description" of the quantitative circumstances of chemical change without invoking the concepts of discrete atoms and molecules; and there is no need to employ these concepts as a stimulus to further investigation.

[1] It should be noted that Duhem considers that experiments *disprove* the existence of molecules.

Thus there is nothing that renders their introduction indispensable, and, if the preceding argument is sound, it should be avoided.[1] In the writer's own practice any inconveniences that would result from this avoidance are (he believes) evaded by the early introduction of the *terms* "atom" and "molecule" in senses which preserve all the implications necessary to make them useful instruments of description and investigation without carrying the further and possibly illegitimate notion of material discontinuity.

In the earlier stage of this use a "molecule" of a compound substance means simply the "small mass" of it under examination; an "atom" of an element is the smallest quantity of that element that can be removed from the molecule or added to it so as to produce a homogeneous result. Thus an "atom" of oxygen can be removed from a "molecule" of puce-coloured oxide of lead by heating it, while the yellow oxide thus produced can be made by reduction to yield another "atom." To state that a molecule of the puce-

[1] The introduction has been defended on the grounds: (1) that it helps to "train the scientific imagination," and (2) that in atoms and molecules we have an "explanation" as opposed to a "mere description" of phenomena. The former plea is too obviously connected with what Professor William James would call the "chromo-science" of the popular lecture to call for serious argument. For the relation between description and explanation here the reader may be referred to the author's paper on Causal Explanation in the *Proceedings of the Aristotelian Society*, 1907, or to the chapter on Science Teaching in Adamson's *Practice of Instruction.*

coloured oxide contains two atoms of oxygen is, then, a brief and effective way of summarising much of its observed behaviour. Moreover, such a use of the terms performs the second function expected of the "conceptual machinery" of science: it suggests further investigation. Are the two "atoms" of the element identical in weight? The discovery that they are so in this case and in others leads to the attribution of a quantitative significance to the terms atom and molecule. The discovery of the relations known as the "law of reciprocal proportions" makes an important elaboration of this quantitative significance possible, and leads to the establishment in due course of a series of "atomic weights," with consequent "molecular" weights, constructed on the usual conventional basis, but still without any reference to the hypothesis of discontinuity.

The third stage is that in which the concepts of atom and molecule are applied—with the same limitations—to the description of the phenomena of combination in which gases are involved. The study of some simple cases has already brought the conviction that the numbers of combining atoms of gaseous substances can be predicted from the relations of their volumes. The first form that this conviction takes is the proposition that under identical conditions of temperature and pressure atoms of all gaseous elements occupy the same volume. Further consideration

of such phenomena as the combination of hydrogen and oxygen to form steam, of hydrogen and chlorine to form hydrochloric acid, leads to a second proposition: the molecule of a compound gas occupies the volume of two gaseous atoms. These two propositions can be made to yield (and probably in a more direct and simple way) the results that follow from Avogadro's Law—which is, of course, an interpretation of the same original facts in terms of "material discontinuity." Thus when carbon is burned in excess of oxygen a molecule of "carbonic acid gas" is formed without change of volume: the combination must therefore have affected two atoms of oxygen. Similarly, a given volume of nitric oxide combines with half as much oxygen to yield the original volume of nitric peroxide: the molecule of nitric oxide must be converted into a molecule of the peroxide by the direct addition of an atom of oxygen.

In this way it is possible to cover all the ground usually included in an elementary course without appeal to the assumption—certainly unverifiable at this stage—that matter is essentially discontinuous. But the pupil who passes on to the systematic study of carbon compounds can hardly make progress without using the concept of the molecule as a (chemically) ultimate material system both to "resume" the phenomena within his range of observation and to guide his further

explorations of the field.[1] At this point then this final qualification of the now familiar term should be introduced with an explanation —for which the pupil should now be ready— of the circumstances which make possible a divergence of opinion as to the actuality of atoms and molecules.

The reader will have no difficulty in finding problems similar to the one here briefly discussed. What is the origin of the common tendency to believe that a "compound" such as water actually contains its "elements," and how far should the teacher make use of it, how far check it by criticism? What is the precise logical status of "heat" and its so-called "laws of transference"? How should the notions of "force" and "mass" be taught so as to bring out clearly their relation to the great group of observable phenomena with which they are concerned? These and the many similar questions of great importance and interest to the science teacher admit of only one mode of satisfactory answer. The teacher must in each case enquire what are the facts of observation to which the explanatory idea is relevant, and must then determine whether the idea consists merely in a grouping of these facts or whether it purports to represent existences, themselves unveri-

[1] The consideration of ozone, the dissociation phenomena in elements and certain vapour densities may be used as the motive for passing from the earlier position to the later.

fiable,[1] deduced from the verifiable data of observation. In the latter case, the general considerations set forth in this essay suggest a mode of pedagogic treatment comparable with that exemplified in the case of atoms and molecules.

[1] It is perhaps unnecessary to point out that the study of the emergence of the idea in the history of the science is frequently a most useful clue to its real significance.

VII

THE CLAIMS OF "RESEARCH" WORK AND EXAMINATIONS

BY THE EDITOR

THE teaching of Science up to University standard may be roughly divided into three stages: (1) the Nature-study stage, lasting until the age of twelve or thirteen; (2) the Preparatory Science stage, from this age until about sixteen—a course in which all members of the school should join; and (3) the Special Science stage, in which boys, for their profession, or on account of particular interest in the subject, deal more systematically with one or two branches—physics, chemistry, biology, as the case may be. Such a division of the work into three parts has been ably discussed by Dr. Nunn,[1] who argues that each part corresponds roughly to a stage of mental development. The cleavage shows itself in the writer's experience; it will no doubt be less marked in some institutions than others.

Work in the first stage varies much from

[1] J. W. Adamson, *The Practice of Instruction*, 1907.

school to school, both in amount and kind; for our present purpose its chief value is to send up boys and girls to the higher classes with an interest in observational study, and—as Shenstone urged—with the feeling that, however much labour and thought must be given to experimental detail, it is still "worth while."

In the second stage there is a fair uniformity of subject-matter in different schools:[1] topics such as mensuration, mechanics, heat, the chemistry of air and water, of acids, bases, and salts, are dealt with; or botany may be chosen—notably in girls' schools—or, perhaps, towards the end of the time, the elements of electricity and magnetism. Mr. Eggar, in *Public Schools from Within*, gives reasons for choosing heat and elementary chemistry as the most suitable subjects to fill the small time he asks for—time doubtless meant to be a minimum even for the older Public Schools. There is good ground for Mr. Eggar's view that "not every boy takes kindly to mechanics," and that the apparatus described and exhibited by Mr. C. E. Ashford is too elaborate for the junior student who is not to be a specialist; but with a practical class, fourteen or sixteen in number, of average intelligence and some previous cultivation on the observational side, it is possible to get up a very fair interest in machines. Pulleys are full of "life";

[1] Cf. Mr. Latter's recent *Report*, referred to in preface.

and the final impact of a truck on some improvised buffer, after a successful run on an inclined plane, is sugar enough to coat the pill of tabulating and plotting the results. Especially if the apparatus needs to be refitted or adapted to some extent, and calls for filing, hammering, or oiling, the occupation becomes a real pleasure. And in optics, too, quite a gratifying interest can be developed, if the geometrical side is relieved by the actual construction of microscopes, investigation of hairs, etc. etc. All this suggests that we have not yet reached the stage where examinations have to be considered, and such is our hope. It ought to be possible, at least in the case of boys who will stay at school until nearly eighteen, to stave off till then external tests which affect their prospects or reputation.

The elementary science we have been discussing can well be treated in close conformity with heuristic principles. The teacher must give to these boys, of from thirteen to sixteen years, as little direct information and explanation as possible regarding the problem in hand; encouraging them to form their own working hypotheses and to test them without much help. Help in some measure is nearly always needed; but since so much of school work tends to take the form of direct instruction with little appeal—by the student's own effort or in any other way—to

first-hand evidence, it is good that the authority-factor should be reduced in the laboratory to a minimum. This puts a greater strain on interest at the start, but gives a steadier purpose in the end.

Professor Armstrong's many and vigorous contributions to the subject[1] have already had a large hand in creating new practices and spreading conviction in favour of training alertness, thoroughness, self-reliance, rather than of communicating information alone; and it may seem to some needless to put down again what has been so often written before. But science teachers still growl here and there at what they regard (perhaps rightly) as excesses of heuristic fanatics, and there is yet room for some defence on the heuristic side. To feel successful in its application the chief conditions are, on the one hand, to give the method a fair chance, i.e. to have a long course and a strong course in physics and chemistry; and on the other hand, not to be tied by it when it appears to need supplementing by direct teaching.

Given laboratory work of any sort—and now it is in England an accepted fact—it must become in some degree heuristic. We have to reckon with the independent curiosity of boys; we have to reckon with the complexity of the

[1] *The Teaching of Scientific Method.* Macmillan, 1903.

phenomena which we are always trying to simplify for the purposes of study. *Die Bösheit der Materie*, as a German friend once called it—the "cussedness" of matter—will provide an outlet for original effort. The teacher should exploit and extend this application of free judgment on the part of the boys, being always restrained from giving prompt and obvious suggestions: so to find a new interest in the growing resourcefulness of his pupils when the subject-matter itself may be losing freshness by dint of repetition.

It is possible to defend the heuristic position and yet to be alive to its dangers. We cannot rigidly exclude all information which has not been obtained at first hand. If it were possible, the result would probably be a lessening of interest and an eventual barren condition of the mind. Each teacher is no doubt unconsciously—or consciously—judging from day to day which is the particular thing required to help a given individual or a given division over a difficult place. If we realise that those who are most keen to work and to discover are also keenest to talk and to read, we shall see that there is a certain reciprocity in these things. If information at second hand is continually being applied and tested by a boy who is working out some little problem of his own, he is clearly treating his work at least as critically as does the ordinary scientific man, who depends in a

hundred ways on information which he accepts from a limited number of chosen accredited authorities. But this is an aspect of the case which generally adjusts itself; and we must not be led too far from our main contention.

To repeat then: We defend in the second stage of teaching—between the ages of thirteen and sixteen—an application of the heuristic method as liberal as may be: thorough-going in the sense of acquiring as much first-hand information as possible, and depending as much on independent endeavour as possible (but not in the sense of discouraging private reading and discussion on all sorts and conditions of scientific matters). The work so done will not reach, except in very easy experiments, a high degree of accuracy; but laws will have been arrived at in a rough-and-ready form: approximate: not so well established as to be applied always with confidence by a critical pupil, but well enough for the needs of the average person of the given age. The work regarded as a body of exact information will need to be further supplemented at a later stage.

Now at the end of our second stage boys begin to think of professional careers, and discover that they need to pass examinations; and in considering such tests inevitable, and in some degree useful and good, the present writer may have to part company with some adherents of the "research" school—probably with Professor Armstrong him-

self. But supposing we only consider examinations as unavoidable in the present state of affairs, we still have to ask the question: How is the work to develop beyond this point? In the writer's experience the examinations are the various matriculation tests of the newer Universities, the Army Preliminary, and at a higher level, the examinations for scholarships at Oxford and Cambridge. There is a measure of uniformity about them: they are nearly all modelled on lines in so far modern that boys who have done experiments, or have seen them done, are likely to score marks thereby; and in examinations of the higher grade there are "practical" papers.

Questions may be set, for instance, in mechanics or chemistry, referring to experimental work done in early days; but the early work alone will not be enough: to have it at his fingers' ends the boy will have needed not only to take up new chapters of his subject, but also thoroughly to revise the old. He must read books, repeat experiments, work numerical examples. And he will seldom have quite enough time: for the boy of average intelligence only gets through with a struggle. So, though the examinations are based on experimental syllabuses, the standard required and the lack of time will cut down chances of continued heuristic treatment. This is by no means all loss; for the extra grind involved in close reading and paper work, with the straightforward

stimulus of bread-and-butter urgencies, is a fine discipline for an easy-going, not brilliant boy, who may have scraped through the course of a kindly "modern" teacher with too little real wear and tear; and even those who have worked best are often glad of the change to a more coherent, deductive ordering of the subject.

Some measure then of working for examination will have its place in the last years of school life; there seems to be more use in wrestling with such tests than in railing at them. The crucial question is: Does the admission of so much mean the abandonment of the "research" method—until the problematic future when the occasional boy has become "post-graduate"? If the only available time is class-time, then probably such a fate is sealed; but to a pupil of fair keenness the solving of an experimental problem makes, ere this, a strong appeal; and if some sort of prize can be offered as an extra stimulus, and if the laboratories can be put, to some extent, at the disposal of boys in their *free* time, it is possible that good work may still be done. A great number of problems need not be dealt with in the course of the year; on the contrary, the fewer the questions studied the better, so long as three or four hours are put in every week. Laboratories are doubtless not equally accessible in all schools, and in the case of a day-school questions of time and distance would arise;

but we have heard of boys at such a school carrying out the sort of private investigation we advocate, and lecturing on the material gathered.

This matter, the early tackling of really independent work, is especially interesting for teachers devoted to the history of their subject. Is it compatible with keenness for the didactic suggestions we can get from the slow growth—in history—of clear ideas, to encourage a boy at seventeen to plunge into the middle of wireless telegraphy, or the chemistry of the rare earths, or the study of enzymes? Yes, if he is minded to do such a thing. The history of the science is of chief value to the teacher; to him it is a pathfinder in thorny places (and an intellectual pleasure at all times); but the enthusiastic junior student has found, instinctively, a number of short cuts over relatively open ground, and it would be pedantic to call him back merely to show a path of which he does not feel the need. Just as a small boy who is keen on electricity may construct a voltaic cell and perform certain experiments, without a clear idea of the chemical changes taking place, so an older boy may be quite successful in an advanced piece of work, although unable to answer all test-questions which naturally suggest themselves to the teacher. To make progress with a minimum of knowledge is the mark of a most important sort of ability; which depends in great part on grasping, quickly

and instinctively, where it is safe to apply the said minimum and where not.

We, who for teaching purposes must keep up a nodding acquaintance with a range of work such as (when it has grown a stage) is material for three or four University professors, may not realise in ourselves how concentration helps an effort along one line. The accumulation of knowledge is to some extent an obstacle, both for teachers and taught. True, added knowledge is always a stepping-stone to new ranges of possible initiative; and no doubt there are more such ranges calling for attention than ever before; but the frowning accumulation of stepping-stones is apt to look more essential than it really is. If native independent wit can run its course alongside the more orthodox progress of the receptive intellect, much more vitality goes into the effort. It seems inevitable that examinations of the school-leaving type should put a premium on receptivity; that holds good even in Germany, the land of research; all that can be done should be done, to foster the other sort of growth.

To those who urge that any form of loose, inaccurate knowledge must be bad, it may be answered that the present defence of such "teaching" is meant to be limited—strictly—to knowledge that is to be *used* in doing something. If there is no pressing interest of an active sort, then there is no excuse for going a little way into

any chapter and stopping at haziness; unless, indeed, difficulties are insuperable. And if it is urged that an active interest in new enquiries is too much to be expected of schoolboys, and is really only a pleasant fancy of an unpractical teacher, we reply that some of the famous people, at least, have made an early start. Galilei came upon the matter of the pendulum at the age of seventeen; Perkin was a research assistant at seventeen; Kelvin published a paper on Fourier's expansions at the same age; and though we may not hope for results of this magnitude, yet we may hope for some results. There is certainly much native keenness which in early days goes begging for the want of a little guidance; and by the time that an older eye has seen more clearly wherein opportunities consist, bread-and-butter studies, administrative responsibilities, *et hoc genus omne*, may crowd out pure science altogether.

The teacher who goes out of his way to encourage early effort will find, of course, that he is adding greatly to his own work; but it is a most interesting sort of work, and it repays the teacher in one practical way; for a few people in a school who have been made really keen on one special question or another raise the standard of interest of the rest; free-time work may be permitted for conversation when class-work would be barred. This gives renewed interest in points of ordinary

class-teaching. So-and-so's direct-vision spectroscope "comes up" spontaneously under prisms; A's model aeroplane or B's vacuum-tube become familiar, and give new points of contact. No doubt commonplace things like cameras, toy-motors, and footballs may be even fuller of suggestion, but they lose a little in being commonplace.

A word may be added to explain more in detail the kind of problem that has been recently attacked in the writer's laboratory, with fair success, in the "free-time" way that has been described: construction of a sliding-coil galvanometer with determination of resistance and curve showing sensitiveness; construction of a rather large electro-magnet, with tests of field-strength by ballistic method; construction of "cymometer" and measurement of wave-lengths of transmitters; "wireless" signalling (Lodge-Muirhead) over half a mile;[1] construction of reflecting magnetometer and tests of various steels; separation of cerium, lanthanum, and didymium in cerite, with a study of the absorption spectrum of the last-named; study of niobium and tantalum in columbite; study of the hardness of various well and other waters in the district; working up of weather reports, photographic and electric effects of radio-active substances, etc. etc.

[1] With forty-foot poles this only requires a toy coil giving a quarter-inch spark,—and a simple carbon-contact coherer.

It is worth noting that the common practice in junior laboratories of working in pairs can sometimes be employed with advantage at this stage too.

How many boys in a school will find interest, time, and energy to carry out such a piece of experimental work? At a guess it may be hazarded that half the public of available age—sixteen to eighteen—will be interested enough, and half of these will be not too busy. This sounds a small number: only five per cent. perhaps, of the whole school; but as was said above, it all helps to create an infectious interest in science, and so the total result cannot be so easily estimated. In such a way a number of those who would not attempt a piece of work needing really hard thinking may be, and are, encouraged to attempt simple bits of apparatus-making, which often turn out of great educational value.

To sum up. The heuristic method, which is commonly practised in dealing with introductory science work, and which must give place, when the examination stage is reached, to a speedier method of accumulating information, may be followed up with work of an attractive sort done in free time, to the advantage, eventually, of the three concerned: subject-matter, teacher, and pupil.

VIII

SCHOOL MATHEMATICS IN RELATION TO SCHOOL SCIENCE

BY T. JAMES GARSTANG, M.A.

IN this paper we propose to discuss the possibilities of school mathematics, especially from the point of view of its correlation with school science. Mathematics most suitable for school purposes is neither the same science as that studied in universities, nor as that defined as "pure mathematics," by those dealing with the modern problem of mathematical logic. School mathematics cannot possibly be limited to processes of mere logical deduction and to propositions concerning purely abstract objects and relations; though it ultimately may concern itself with such truths, it has regard also to the immature nature of the child-mind. In accordance with this latter necessity school mathematics begins with separate things and facts, and with any questions relating to number, size, and form arising therefrom; it passes, through processes of comparison and induction, to statements and truths of some though perhaps of very limited

generality; and towards its close it approaches with some hesitation the deductive systems of the higher university stage. If a verbal definition of the content is required, then that given by Professor J. W. A. Young[1] may be adopted for practical use :—

> " 'In all domains of mathematics those parts are to be called elementary which can be understood by a pupil of average ability without long continued special study.' Obviously school mathematics implies suitable methods of approach, namely, those which lead immature and growing minds towards an understanding of the parts of the subject matter included in the course."

Although the definition just given is very useful, especially when the trammels of long-established custom press most severely, yet it hardly emphasises sufficiently those aspects of mathematics which seem important, if not essential, to the question under consideration, namely, the possibilities of school mathematics especially in relation to the *correlation* with school science. The method of correlation which will be described later has developed from certain views concerning the nature of science and of scientific method; and although it is beyond the scope of this article to attempt a full description of these

[1] Professor Young, *Bull. Am. Math. Soc.*, XII, 349, April, 1906.

questions, yet it seems simplest to refer to several well-known authorities, whose published work has had influence on the solution adopted. The late Professor George Boole, in a lecture on "The Claims of Science in Relation to Human Nature," gave the following description of the general question :—

> "Science, then, we may regard as the joint result of the teachings of experience, and the desires and faculties of the human mind. Its inlets are the senses; its form and character are the result of comparison, of reflection, of reason, and of whatever powers we possess, whereby to perceive relations, and trace through its successive links the chain of cause and effect. The order of its progress is from particular facts to collective statements, and so on to universal laws. In Nature it exhibits to us a system of law enforcing obedience; in the Mind a system of law claiming obedience. Over the one presides Necessity; over the other, the unforced obligations of Reason and the Moral Law. Such I conceive to be the true conception of science."

For a formulation of the particular aspect of science which concerns us now, we may turn to the *Grammar of Science*, by Professor Karl Pearson, where we find these passages :—

> "Scientific concepts are, as a rule, limits drawn in conception to processes which can be

started but not carried to a conclusion in perception. The historical origin of the concepts of geometry and physics can thus be traced. Concepts such as geometrical surface, atom, and ether are not asserted by science to have a real existence in or behind phenomena, but are valid as shorthand methods of describing the correlation and sequence of phenomena. From this standpoint conceptual space and time can be easily appreciated, and the danger avoided of projecting their ideal infinities and eternities into the real world of perceptions".[1]

"The progress of science lies in the continual discovery of more and more comprehensive formulæ, by aid of which we can classify the relationships and sequences of more and more extensive groups of phenomena. The earlier formulæ are not necessarily wrong; they are replaced by others which in briefer language describe more facts. . . . They are what the mathematician would term 'first approximations.'"

Further on in his book[2] Professor Pearson tells us that the validity of a conceptual mode of classifying and describing perceptual change depends "upon the power it gives us of briefly resuming the facts of perception or of economising thought."

This leads us naturally to the views of Professor

[1] Page 191 (second edition). [2] Page 194.

E. Mach, who considers that "economy of communication and apprehension is of the very essence of science";[1] and that "mathematics may be defined as the economy of counting."[2] More generally that "it is the object of science to replace, or *save*, experiences, by the reproduction and anticipation of facts in thought. Memory is handier than experience, and often answers the same purpose. . . . Science is communicated by instruction, in order that one man may profit by the experience of another. Language, the instrument of this communication, is itself an economical contrivance." So far, so good. But although Professor Mach goes on to contrast to a certain extent the restricted nature of national languages with the universal and international character of numerals, algebraic signs, chemical symbols, and other written languages of similar kinds, yet in this particular passage he does not emphasise sufficiently the special properties of notation. Where national language enables a limited group of people to communicate ideas about all subjects of interest, an adequate notation helps all men to communicate ideas about only one subject of interest. Where national language is of use chiefly in the expression of thought, adequate notation not only has the power of economising thought by brief expression, but fulfils its most remarkable function only as an instrument for the

[1] Mach, *Science of Mechanics*, p. 6. [2] *Ibid.*, p. 486.

discovery and development of thoughts about the subject-matter for which it has been specially devised.

Undoubtedly Babbage, as Professor Mach suggests, was quite familiar with these ideas; he attempted through his calculating machines to secure by material structures the automatic accuracy which is so characteristic of good notation, and to retain, as it were, sufficient power of adaptation to meet any contingencies. Though he failed to complete his machine, he was certainly right in describing notation[1] as a "language of unrivalled power, enabling the mind to carry on processes of deductive reasoning of almost unlimited length," with an automatic power of self-correction.

Considerations such as the foregoing have led us to adopt certain conclusions in regard to teaching mathematics in schools, among which are the following: the necessity of personal experience to awaken thought; the supreme power of an adequate notation for the expression and development of thought; and the gradual advance towards perfection, which implies the reproduction in some way in the class-room of the kind of racial experience which at various times has stimulated the great original discoveries recorded in the history of science.

[1] C. Babbage, in the *Edinburgh Encyclopædia* (1813–30), art. Notation.

Let it be admitted that such conclusions were reached only after much thinking; and that this thinking was necessitated by a certain failure, experienced during some years of teaching physical science, to find in the text-books and practices in ordinary use twelve years ago either sufficient stimulus to awaken thought or any factor which promised to develop real power of mind in the average pupil. As the result of such experience, and by some readjustment of duties, a very serious attempt was made to reproduce in an elementary way, suited to the capacities of young pupils, the original mathematical work of the times of Fermat and Descartes, which led, through the investigations of Wallis and Barrow, to the great discoveries of Newton, Leibnitz, and their successors in the Differential and Integral Calculus.

The original basis of these discoveries was the synthesis of algebra and geometry by Descartes and others; and the possibility of applying such work to elementary teaching seemed to lie in the complete synthesis of arithmetic with algebra and geometry. Fortunately at this time (1898) Professor Chrystal published his *Introduction to Algebra*, and so introduced into elementary mathematics those graphical methods so necessary to sound mathematical progress.

After developing the course of algebra for

some years on his lines, full confirmation was obtained of his statement[1] that

> "By the constant exercise of graph tracing the beginner acquires through his fingers three fundamental notions, viz. the idea of a Continuously Varying Function, the Conception of a Limit, and the method of Successive Approximation."

Some additional features of the method of teaching adopted seem to be worth specific mention: firstly, the Froebelian principle of "learning by doing" was, we think, much emphasised by actual practice; secondly, our method of class-work removed all just grounds in this instance for the complaint made against the teaching of graphical algebra—that tedious and unfruitful calculations are necessarily involved, for each member of the class was required to calculate one or more values of the function for different values of the variable. These values were then written up on the blackboard and were thus available for every one when plotting the graph. In such ways there was much co-operation for the purpose of saving tedious labour; but that sufficient emulation remained among the individual members of the class seemed to be proved by frequent little private competitions

[1] Chrystal, *Introduction to Algebra*, 1898. Preface, p. x.

for calculating any extra values required for the graph.

The first stage of the course was directed towards educating the power of mathematical intuition. No formal proofs were attempted. For instance, the correspondence between linear functions and straight lines was accepted as obvious. But although it seemed very advisable to base the course on facts sufficiently obvious to be admitted without question (in logic this is equivalent to taking theorems as axioms), it seemed also necessary for future progress to introduce technical names as the occasions arise, after the proper notions had been grasped.—In this respect the graphical method has marked superiority. Words like coefficient, constant, index, degree, etc., are difficult to explain with interest sufficent for comprehension, but they have become almost self-explanatory after visual presentation through graphs.—The course worked through commenced with linear functions, varying in coefficients and in constants. Next an advance was made to simple functions of the second and perhaps of the third degree. After this the introduction of fractional functions led to the notion of infinity, and sometimes to discussions on discontinuity. But this side of the work has developed so much recently that perhaps enough has been said about it.

Here it seems convenient to describe in some

detail an experiment carried out at Bedales School, in the correlation of school science and mathematics; an experiment which lasted sufficiently long to show interesting results.

The physical-science classes were organised to supply first-hand experience of a kind suitable for mathematical treatment. The various experiments were quantitative in nature; the results were recorded and then plotted on squared paper. The points thus obtained were connected in the ordinary way by straight lines or curves, according to the experiment attempted, though at times a certain amount of smoothing was required to get a tractable result. From these remarks it is obvious that in general the problems presented for mathematical solution were of an inverse character—given a graph, it was required to find the corresponding algebraical function.

Pupils in the course of their work met with some or all of the following graphs. These were obtained by plotting the numerical results derived from suitable experiments, which are implied by the brief references under each heading.

1. Linear:—
    Temperature F—C.
    Force of Friction—Pressure (planes and pulleys).
2. Parabolic:—
    Path of Projectile.
    Distance—Time (in the case of inclined plane and free fall).
    Time-period of pendulum—Length.

3. Inverse First Power (or Hyperbolic) :—
   Pressure of gas—Volume (Boyle's Law).
   Position of image—Position of object (in lenses and mirrors).
4. Inverse Squares :—
   Light intensity—Distance from source.
   Magnetic intensity due to a pole—Distance.
5. Cubic :—
   Depression of a bent beam—Length.
6. Inverse Cubic :—
   Intensity of field due to short magnet—Distance.
7. Exponential :—
   Excess temperature of body cooling in vacuo—Time.

The list just given is not intended to be complete, especially on the experimental side; but rather to indicate the range of work presented for mathematical consideration. And it is perhaps advisable here to state that no sharply defined scheme of correlation was ever drawn up; but much faith was placed in the mutual help afforded by the work on both sides; some pupils responded more readily to the experimental work, others to the mathematical discussions; but all received much benefit from the inevitable alternation of mental attitude. A definite illustration of this point has been frequently provided by work done with two thermometers, one Fahrenheit, the other Centigrade; pupils who have found the beginning of graphical algebra without much meaning have been encouraged to make further and successful

attempts to overcome the initial difficulties through plotting the graph from their own data.

Concurrently with the earlier part of the practical physics the second stage of the graphical course of mathematics was under development. The first step here was to lead up by suitable illustrations to the notion of a limit. The next step taken was to apply the method of limits with suitable notation to the calculation of tangents to the simplest curves. Beyond the notion of a limit, only easy algebra is required for this purpose. Then many of the curves already drawn during the first stage were treated in a similar way, and the old work and note-books put to further valuable use.

After this introductory course of limits, the third stage was commenced by a recapitulation of the work in the notation of the differential calculus. This notation is more powerful and enables the course of tangent drawing to be extended with comparative ease. The introduction of integration as the operation inverse to differentiation presented little difficulty to classes taught from the algebra of Professor Chrystal; but the discussion of the relation between integration and the areas of plane curves was always treated as the occasion for attempting formal proofs applicable to special cases. This part of the course involved a return back to algebra and the method of limits. The final problem of the third stage was the calcu-

lation of the function of the second degree to a curve determined by a given table of values suitably chosen, an inverse problem presented in the course of practical physics already mentioned.

The fourth and last stage of our special course introduced the differentiation of the circular functions, both direct and inverse, and ended with the calculation of π to several decimal places, by means of Gregory's series obtained by suitable integration. The exponential functions were introduced graphically to the class as a whole; but detailed analysis was reserved until specially required.

Such work lasting through some five or six years has proved conclusively that the average pupils of school age, both boys and girls, can understand and appreciate the methods of elementary calculus, provided they are working concurrently at that kind of physical science which presents problems for solution requiring the calculus. In more recent years the whole work of the school has undergone development and differentiation, which has interfered, temporarily let us hope, with the further progress of our experiment in correlation. But the later results, though apparently adverse, have not been without some value; it has been found that pupils taking mainly biological science, or perhaps devoting much time and energy to music, cannot appreciate the higher notations of mathematics through methods of

teaching quite intelligible to pupils of about the same age who are studying physical science.

Such experience is a useful reminder that, after all the attempts to arrange the various mathematical subjects in a perfect logical order, there is a very human element in teaching which requires more consideration from responsible authorities. The difficulty of teaching pupils in the same class, when some have received good but others indifferent training in early years, is real evidence of the necessity of attending to a wise psychology. Without wishing to question that the deductive is the proper method in pure mathematics for the developed mind, it seems necessary to point out that in school teaching the inductive process of the mind requires the most definite care; for the inductive process is a vital factor in promoting healthy and vigorous growth of mind and brain during the early years of youth, and in mathematics especially this vital process is in constant danger of suffering real and perhaps permanent harm from a system of examinations admitted by many to be too dominant in the regulation of educational affairs.

We may admit that the mind requires training in order to reason correctly, but we cannot admit that the method of this training in schools must be determined by any system of logical deduction from abstract definitions and axioms, however suitable to university work. It is certainly

good psychology not to ask beginners to prove the obvious; and we may hope that at no far distant future many will be found to agree with Professor Cajori, who has stated that the line of progress is to take much more for granted as evident to the eye than present customs permit, but to do this openly with no attempt at deductive proof. Present conditions are not favourable to mutual correlation; for instance, the basis of map-drawing in geography and in simple surveying is the assumed similarity of equiangular triangles, but in geometry lessons this essential truth may not be assumed and is not attained until after years of work. It is probable that from such contradictions much of the general distaste for mathematics arises, and that in their removal lies the possibility of a general co-ordination of school science and mathematics, which would not only assist an economical distribution of effort, but also go far to promote a habit of scientific thought in the educated public.

IX

CO-ORDINATION OF PHYSICS TEACHING IN SCHOOL AND COLLEGE

WITH SPECIAL REFERENCE TO ELECTRICITY AND MAGNETISM

By ALFRED W. PORTER, B.Sc.

THE living material with which a college lecturer begins his work is the finished product of a school career. This fact alone would justify one whose teaching experience is confined to university work in considering the question of teaching in schools. Besides this, at the present day, there is considerable overlapping in the two grades of study. Schools advance in independence of college curricula except in so far as they are regulated by examinational needs. There is no co-ordination between the two; there is not even uniformity in the schools themselves.

This system (or lack of system) must be contrasted with that in Germany, where the schools are governed by the State and a lad's college career is a truer sequence of his school training. We may reasonably hope that the freer system

with us will ultimately lead (largely by the method of trial and error) to a much more satisfactory scheme of education than one which was made rigid in the beginning. But while the evolution of the perfect system proceeds, much difficulty is experienced (arising from the lack of uniformity) in connection with the transition from the sphere of school to that of college. The question as to where a school course should end and the college course begin is specially complicated in the case of the study of science in consequence of the very precarious foothold which science has yet secured in the majority of schools.

The ultimate answer to this question will probably be very different from the one which is suited to present conditions. As the scientific equipment of school laboratories increases, and the time which can be devoted there to science is also increased, it may become possible for much of the elementary work to be transferred from college to school. Such a transference would, of course, require a readjustment of the existing higher curricula of college. The only alternative to this is that, as the school teaching becomes more efficient, the average age of leaving school should diminish. This alternative is one which ought not to be lost sight of. The trend of development seems to be against it; but in certain quarters it would be looked on with favour. For example, Professor Armstrong in his contribution

to the Reports of the Mosely Educational Commission (1903),[1] after intimating that the entire system of education seems to require reconstruction from bottom to top, asserts "the greater part of the work which is now done—far too late—at college might then be done at school; or still better, college might be entered with advantage at sixteen." On the other hand, objections connected with the formation of character can no doubt be urged against early school leaving—objections which could be removed only if in the simultaneous reorganisation of the college career the school influences were successfully replaced. The ultimate selection between these alternatives must turn upon the decision as to the range of a subject which can best be taught in the atmosphere of school.

Under existing conditions I am convinced that many schools attempt far more than their exiguous equipment warrants. The mischief done is greatest when the training is merely to enable a man to pass an examination and the subject is one which he will not be required to take to a further stage at college. To give a single example: this remark applies to any school preparing for the First Medical Examination of London University. No physics is required from the embryo "medical" except in preparation for this preliminary examination. Is

[1] Page 20.

it right that this training should be allowed to be given under the meagre and restricted conditions which are possible in a school? There never was a time when a knowledge of physics was so necessary to a medical man as it is to-day; and it should be imparted under the most generous conditions. Unfortunately the successes which can be obtained at examinations are tending to encourage the opinion that the school training in physics is quite sufficient. The lads will only realise later the insufficiency of their training for the career that is before them.

When a man takes the subject to a further stage at college the wrong done by an extended though narrow school course is not so serious because, to some extent, it is capable of subsequent rectification. But many men have their careers spoilt merely owing to insufficient grounding. I say without hesitation that such men would have done better if they had left school earlier.

These considerations apply to fairly specialised teaching such as till recently has been almost exclusively given at college. I will now pass on to the consideration of the more elementary work; and in order to keep within the space allotted to me, I will restrict the question to the teaching of elementary electricity and magnetism.

Judging from the results which come under our observation many of us are doubtful whether

electricity is a subject suitable to be taught *formally* in a pre-collegiate period under existing conditions. By the adverb "formally" I am distinguishing between what aims at being a complete course up to a definite standard and the more informal introduction to the subject to which I shall refer later.

One source of difficulty is that which we feel even when teaching it in the university: the difficulty which arises from the gross ignorance exhibited by the average boy of the necessary mathematics—simple though it is. Contrast the ideal boy of Professor Perry (whom he describes in the perfect tense)[1]—the boy of the age of fourteen "who has learnt trigonometry," who can also "differentiate and integrate x^n"—with the real boy of sixteen or seventeen who has not done so and who does not know what differentiation means.

Until this state of things is remedied the ways of science will indeed be hard. Cannot mathematicians, however, see their way to develop their subject along lines more suitable to its applications without sacrificing the logical order which is necessarily so dear to them?[2] Unless this can be done a twofold development must

[1] *Discussion at Johannesburg on the Teaching of Elementary Mechanics*, 1905, p. 5. Macmillan and Co., 1906.

[2] This question is more fully considered in Mr. Garstang's paper.—ED.

eventually replace the existing one. Alongside the logical and abstract treatment in the mathematical department—a treatment so necessary for all who have the mathematical faculty and who will ultimately become professed mathematicians, so educational also for those who will not—will proceed a practical treatment on lines suitable for immediate application. Both may be given by the same teacher if he possess the necessary qualifications; but in the majority of cases the latter will be much better given by the teacher of physics because he is more alive to the possible applications. *Both* courses should be taken by both kinds of pupil. We are decidedly against restricting a boy to the practical side because he is going to be an engineer; and we think the mathematician is only half educated who has not come into direct contact with it. There is much to commend this twofold system in preference to a half-hearted acquiescence of the mathematician in the demand for a practical treatment. Of course, much can be done, and indeed is often done already, by the physics lecturer in an informal way towards this end; but it is a great deal better to have the system officially recognised, and not to render oneself liable to a charge of muddying the waters of pure thought supplied by another department.

If the difficulty in respect to a pure mathematical equipment is removed, there remains the

difficulty in respect to the insufficiency of a knowledge of mechanics. No formal course on electricity should ever be given prior to an introductory course in mechanics; yet this is often done. The subject of electricity and magnetism involves almost at the beginning the notion of force, for we measure a charge of electricity by means of the force exerted. How can the teaching of this part of the subject be anything but cram unless accurate mechanical conceptions have been previously imparted? It is in vain to reply that use may be made of the pupil's personal experience in exerting force, and that this knowledge will be temporarily sufficient. It is mischievous to teach that force is measured mechanically in terms of our sensations. Let any one who doubts this statement turn over in his own mind exactly what would be meant by asserting that the sensation in lifting one hundred pounds is double that in lifting fifty; and particularly let him ask himself further whether or not the assertion is true.

So, if this be admitted, care should be taken to ground a boy first in mechanics. If he has done none, the formal electrical course should be postponed. To ensure the possibility of arranging the courses accordingly, the mechanics should be taken by the physics lecturer. Indeed, it should be recognised that it is nothing more than the most fundamental of all the different branches

of physics. It should be taught as such with proper experimental illustrations and suitable laboratory work. Unless this is done there will always be a sense of detachment between it and the other branches of physics.

It may appear as though I am tending to discourage the formal teaching of electricity. My aim, however, is the contrary; it is to prevent it being badly taught. With adequate tuition in mathematics and mechanics as a preliminary, the greater part of the difficulty is removed. It is in making use of terms (such as force, work, etc.) which are only half, if at all, understood that disaster arises. As soon as this preliminary knowledge is acquired the way is open for perfectly sound elementary courses on electrostatics, magnetism, and current electricity. They should be taken in this, the old-fashioned, order. It is of course well known that there has been a tendency to discount electrostatics; this has been especially the case in technical schools. It seems to me that this plan has been bad policy; for this opinion the following reasons may be adduced, though the statement of these reasons for remaining old-fashioned makes a rather long digression. It is useful to make the statement because doing so brings out incidentally the main characteristic of the recent development in electrical theory. Besides the fact that electrostatic phenomena have, in recent years, taken a much

more prominent place in technics owing to the use of high-tension currents, we have the fact, much more important from the philosophical standpoint, that modern views of electricity are based upon conceptions first met with in electrostatics.

In order to indicate the nature of the change it must be mentioned that the trend of Maxwell's teaching, and more particularly of the experiments of Hertz on electromagnetic waves, was to remove the necessity of thinking about electricity as a separate entity. The whole attention was concentrated upon stresses in the intervening medium instead of on forces between electric charges acting according to the inverse square law. It seemed unnecessary to postulate an electric fluid, and scorn was showered upon the newspaper writer who alone failed to realise his archaisms in describing the phenomenon of thunderstorms. But a reaction has come, and it is again fashionable to speak of an electric fluid. Not that we are back in the pre-Faradaic period; the fluid has properties which were undreamed of then. It is divided like matter into atoms, a fact of which the laws of electrolysis may be taken as the most elementary indication. Indeed, the proportionality of electro-chemical to chemical equivalents led Maxwell himself, a long time ago, to speak of a "molecule of electricity"; but then he used this phrase simply to indicate

a "provisional hypothesis," to be discarded as knowledge increased. We cannot go into details here; the point is that the electric charge is once more a fundamental conception: highest philosophy and rudimentary teaching are brought into closer harmony than before, for it is as easy to talk about particles of electricity as about particles of matter; and there is everything in favour of beginning with electrostatics, the branch in which the most simple properties of charges are studied.

There is no room here to outline what a satisfactory course should consist of; the place for that is a textbook and not a page in an essay. Examination syllabuses must unfortunately be taken, in many cases, as the main guide. These, let it be admitted, are usually loaded with ancient material which some day *must* be discarded to give place to new. But in any school which undertakes the formal course (which we would prefer to be given at college, as we have said) new matter must be introduced, whether it is in a university syllabus or not. Hertzian waves, electrons, X-rays, radioactivity: these subjects must certainly not be ignored.

Such a course will not be given to every boy even in the ideal school of the future. But there is a kind of tuition in physics which every one should have, and which I alluded to above as an "informal introduction." Others have written

about allowing boys to play with magnets and cells. Let them "make glass-rubbed electric machines and Leyden jars out of bottles bought cheaply from grocers." Never mind whether or not you can reduce these things to mathematics; perhaps do not even try to do so at this early stage. The interest that can be aroused by this scientific play, the familiarity with things that is gained, are all to the good in connection with later teaching.

The work should not be really desultory. Professor Perry encourages the imitation of Mr. Barlow in *Sandford and Merton*, "who keeps the boys on any one subject just as long as they are interested." My ideal teacher of this stage of work is a somewhat different man; he is one who keeps a boy interested in a subject as long as he keeps him at it. Moreover, he must keep the boy at it past the moment when effort is needed on the part of the boy; otherwise, though a fact may be learned, training has not begun. Some things the pupil may be put to find out for himself, but heuristics is a method too tardy in results to be exclusively employed. Carry it to its logical extreme (which, of course, no one does), and the development of the boy would become as slow as the development of the race. Do not, on the other hand, put him off with a mere dogmatic statement; explain how a thing comes to be

known, and let him test it whenever possible. The dragon which the "heuristikos" assails is the dragon of the old days, when no experimental work at all was taught; he is mistaken in thinking that his enemy necessarily may be found lurking wherever direct instruction is given. A child must be told far more than he could possibly find out for himself; but the spirit of anti-dogmatism should pervade the telling from the beginning to the end.

These considerations lead naturally to the question of the education of the exceptional case. In some schools there is a type of scholar who takes easily to working some one line; he is a born investigator who goes to enormous pains and shows great ability in pursuing work which is of research type, even though the things discovered may be really old: experiments in electric waves, concentration of the radioactive elements in a uranium ore, and the like. This work takes time, and can be done only to the exclusion of other work. What shall be said of school work of this kind which specialises to an extreme in one direction to the detriment of others? The first thing to say is that there are some youths who are best left alone with their teacher; ordinary rules that are laid down for general guidance do not apply to them. They are not the majority; both they and also probably their teachers are exceptional. It is difficult to draw

inferences from the development of these men as to the success of the mode in which they are taught, because they are the sort that succeed in spite of circumstances. That some work of the above kind should be encouraged is one of my articles of faith; but the greatest care should be taken that it does not exclude the vastly important general grounding without which the boy, and afterwards the man, will be continually hampered.

By all means let arrangements be sufficiently elastic that the union between a particular teacher and pupil may be extended beyond the usual period. It is better that this should be rather than the pupil should be transferred to what may prove to be the more uncongenial elementary classes of a university college. But observation of many who have been thus taught has impressed me with the belief that the instances are exceedingly rare in which this mode of teaching can profitably *replace* one which is preceded by teaching of a more formal and general character. Specialisation, even in the university, is being encouraged at too early a stage. With the "one subject" honours in London University our physical students are learning no chemistry or else no mathematics; they are not even compelled to take applied mathematics; our chemists need not even take physics. The loss of power that this implies can only be gauged when it is recalled that there is no hard and fast line drawn in nature

corresponding to our artificial distinctions; a full knowledge of one phenomenon implies a knowledge of all.

If this objection can be validly urged against too early specialisation at college, much more can it be urged against the same fault at school. There is no identity between encouraging research habits of thought and experimentation and narrowing a boy down into a single groove.

X

GEOGRAPHY

BY J. H. N. STEPHENSON, M.A.

"Step by step the conviction dawns upon the learner that, to attain to even an elementary conception of what goes on in his parish, he must know something about the universe."

T. H. HUXLEY.

IT is in some respects a misfortune that the geography of our childhood was practically dead before that general overhauling of our educational system began which has been so marked a feature of the past decade. But the lists of capes and bays, the marshalled array of chief towns and their populations, however useful in themselves, had long been felt to be sterile and uneducational, in that no one group of facts bore any relation to another, and no mental faculty other than memory was brought into play; nor were even the bare facts themselves impressed at all in proportion to their intrinsic importance. Hence, in secondary schools at least, the subject has long been thrust into the background, if not entirely abandoned. The reformer has therefore not merely—as in the case

of other subjects—to point out better methods and win acceptance for them; he is obliged first to convince that the subject is worth considering at all.

It is not the main purpose of this article to examine or vindicate the importance of geography as a subject of study, but since this question vitally affects its relation to science teaching, it may not be amiss to point out that the claims being now more and more strongly urged on its behalf are not altogether new. Arnold saw in it the meeting-point of history and natural science, and J. R. Green spoke of it as a study "which must occupy a foremost place in any rational system of primary education," and again as "the natural starting-point for all subjects of later training."[1]

I would call special attention to the last quotation, because it is as the starting-point of at any rate most subjects of later training that I believe Geography must be accepted, if at all.[2] The ever-widening circle of human knowledge makes it increasingly difficult to reach the circumference at any one point, to do so at more than one, well-nigh impossible; and in order to

[1] I am indebted for these quotations to the Rev. F. R. Burrows, *Geographical Gleanings.*

[2] In the preparatory-school stage; later, when teaching is carried on by a larger staff, there may be a continuation of geography teaching for its own sake side by side with other branches of science.

adapt itself to the changed conditions, our education must aim less and less at pursuing a number of arbitrarily chosen subjects and more and more at establishing a thorough grasp of fundamental principles, and forming a habit of mind capable of applying these principles in any direction that the needs of special work subsequently may demand. The same tendency is observable in the modern treatment of mathematics and also of history. Paradoxical as it may seem, increased specialisation in later life means greater concentration in early education; to illustrate by a metaphor, if fresh storeys are added to the building, the foundations must be strengthened. And surely no subject is better fitted for supplying this foundation than geography rationally studied, training, as it should, the observation and reasoning power as well as the faculties of memory and imagination; lying at the root of all natural science, and touching so closely the social sciences also. As Miss Busk says: "The magnitude of its educative value will be realised when teachers understand that it is a subject which develops the child's ability in many different directions rather than along any one special line, and renders the mind more receptive of new ideas in very varied fields of knowledge."

How then, it may be asked, can the teaching of geography be carried out so as in fact to do what has been claimed for it? Let us take the

case of a boy entering a school at the age of nine or ten, and we will assume that he has learned nothing of geography, though it will be fortunate if he has escaped being burdened with names that conveyed nothing to him and a few tags of information that he could not understand. Mr. H. J. Mackinder has admirably expressed the aim to be kept in view: "The object of the teacher is to build up a conception of the surface of the earth as a product of interacting physical forces, in order that that surface may be intelligently viewed as the scene of social activities"; and to carry out the aim the first step will naturally be to learn something of the interaction of physical forces on the surface of the earth, or in other words, something of physiography.

It is unnecessary to give details of this course, since there is a substantial agreement among the available textbooks as to the general subject-matter and order of arrangement, but the following points may be worth noting. First, those fundamental facts must be specially emphasised which are capable of the widest application, as, for example, the laws of gravitation, of heat and energy, of chemical combination, etc., and it need hardly be said that this should be done with the fullest possible observation of, and illustration from, familiar objects and occurrences. That is to say, the elementary science should at first either be

taught by the geography teacher as geography, or if it is done by another teacher under another title it should be so closely woven in with geography that it might still almost be called by the same name. Thus a very elementary experimental course can be worked out on "salt," or "frost," or "water-vapour," called physics by the physicist, but having the central idea really geographical. Attention should be fixed on the main factors determining the surface conditions of the globe rather than those which have little bearing on them; erosion due to wind, water, and frost, for instance; and in such matters help may be found in observational work near home. Such phenomena as eclipses, stalactites, geysers, and typhoons are apt to have a quite disproportionate importance given to them. I am continually being corrected by small boys for saying that the earth is round like a ball, and am almost invariably told by the same pupils that it is hotter in summer because the earth is nearer the sun.

Having thus gained an insight into the physical forces in their action on the globe, a map will call up in the boy's mind, with the aid of his reasoning powers and some exercise of imagination, a living impression of the main features of its surface. But far more, even than this, what he has learnt will make him unconsciously realise the oneness of nature and the close interdependence of all

those organised branches of knowledge which are called by various names and grouped together as natural science, and as Huxley—the pioneer of a rational study of physiography—claims, "will facilitate his subsequent entry into their portals." Against all this it is sometimes urged that physiography deals with so many sciences that these ought to be undertaken first or there will be a danger of "smattering." Now it is true that the facts on which our knowledge of the earth is based have been drawn from many sciences, but a grasp of these facts in their relation to one another is surely the best starting-point for embarking on the special study of each group. Some regret may be felt by the expert, where the first beginnings of his special study are put into the hands of an amateur; but the loss, which may be a very real one, is, I am convinced, far more than made up for by the unity of conception established; and if geography were made to wait till the astronomer, the chemist, and all the other specialists had first had their say, not only would it suffer by the delay, but natural science, which has too long been hampered by watertight compartments, would be the loser also.

And before we go further it may be well to consider another objection which will be almost certainly raised against this scheme from the start: that it begins "at the wrong end." There

is a growing tendency to urge that geography, like charity, should begin at home, and children taught first to observe and understand what lies around them and gradually feel their way outward to the universe. This idea is in some degree natural and reasonable, and certainly marks a healthy reaction against the older dogmatic methods; nevertheless I venture to believe it is not always safe in practice. The attempt to base everything on first-hand observation ignores the fact that normal children only observe what interests them, and they are keenly interested in knowing why a thing happens; if this can be in any way explained they will readily observe other instances of the same nature, whereas the process of inductive reasoning from the facts observed is often quite beyond them as a rule; thus it is far easier for a quite young child to get a tolerable idea of the solar system than to draw any induction from the varying length of a shadow at the meridian. The scientific explanation is therefore a stimulus to, rather than a natural result of, observation, and the reversed order often fails. Again, the idea that it is simpler to draw scientific conclusions from one's immediate surroundings does not take into account the exceedingly complex factors which go to produce these surroundings. It is in fact far simpler to account for the trade winds or monsoons than to explain the meteorological

conditions on an average English day; or to grasp the main geological formations of the British Isles, and their origin, than to follow the surface evidence of them in a particular locality. The early training in observation is good, but the conclusions drawn from the observations may be confused, inadequate, or misleading. Putting aside for a moment these objections to the method, there remain grave practical difficulties in the way of its accomplishment. A system which imperatively demands specially gifted and highly trained teachers, as this emphatically does, cannot, under present conditions at all events, hope for general acceptance in our secondary schools; while differences of locality must almost inevitably be reflected in the relative importance which the pupil attaches to different types of phenomena.

It should be clearly understood that there is no desire or intention to detract from the value of nature-study. It has its own place, and an important one, in education, and from the point of view of geography it has the greatest use as an accompaniment to and a preparation for the scientific study of the subject; but to base the teaching of geography on first-hand observation alone is to set both pupil and teacher a well-nigh impossible task.

Assuming, then, that our boy has mastered the rudiments of physiography, their result must

next be studied on the life of the globe. It is at this point that physiography too often breaks down, and if it refuses to go further we, at least, must go on, for the elements of plant and animal physiology are as necessary to a real comprehension of geography as are those of astronomy, geology, and the like. They are the links that bind them to the study of mankind in its relation to nature, by turning the knowledge of soil and climate which physiography has given us to practical account, and enabling us to understand the great belts of vegetation, and their consequences, economic and political (as, for example, why we import wheat from Canada and wool from Australia). It is safe to say that without some knowledge of the conditions of plant and animal life the political map of Africa is altogether meaningless. The general study of man will naturally follow, and it is perhaps hardly necessary to plead that a more scientific account should be given of his place in the economy of the world. The teachings of anthropology are another indispensable link in our chain, enabling us to understand something of the varying forms and degrees of civilisation, and I would lay far more stress on this than on the sister science of ethnology, as being the parent of history. Finally, an acquaintance with the broad principles of economics will complete the equipment of our pupil for entering on the study of regional

geography in all its aspects. This I would regard as, in the first instance, little more than a series of exercises in applying with the help of maps the principles already learnt to special areas. The close dependence of regional or applied geography on what, for lack of a better name, may be called general geography—the term physical geography is too narrow—is often lost sight of, while regional geography is made to include almost anything which appears to the teacher or writer as interesting or instructive. Here, more than ever, some unifying principle is needed, in other words a recognised nucleus, so to speak, round which all subsequent information from whatever source may find a fitting place, and from which more specialised study may be developed. Such a nucleus may, I think, be found in a careful application of the conclusions arrived at in general geography to the region under consideration, interpreted so far as need be in the light of history.

A true understanding of the really difficult problems can, of course, only come at a later stage, when with a broadened outlook and a greater knowledge of other sciences, a pupil can enter into local detail without the danger of distortion. Here comes in the importance of continuing geography in the later stages of school work, since much of its teaching can only be realised by older pupils, and because the fruit

of the earlier work is largely lost if the subject is cut off before it has been fully shown that it is the common ground where all other sciences may meet and overlap.

As has been already shown, this earlier work is mainly concerned with the nature of the geographical features and conditions of the earth's surface, and though all along their influence on man is kept in view, it is especially in the later stages of secondary education that the teacher can set to work to classify and rearrange the knowledge previously gained. Facts learned before can now be revised and added to, and grouped in such a way as to bring out clearly and in greater detail how geographical features, forces, and conditions have affected and do affect man in his "social activities," to establish geography as "the meeting-point of history and the natural sciences."

For example, one can trace the growth of towns along what at one time were the open lines of communication, or one can compare and contrast the history of all those countries with a mountain-wall for frontier. Also prominence must now be given to those surface features which are the work of man, and not of nature only: artificial harbours, railways, bridges, canals, and all those means which are helping on a greater unity, understanding, and sympathy between the nations of the world. In the consideration of the

effects of geography on history and *vice versa*, such features are acquiring vast importance ; for, whereas the development of man has hitherto mainly been controlled by the forces of nature, his struggle with these forces has been so far successful that he is now in part controlling them.

The following are some of the considerations for older pupils to enquire into : how food may be found for our millions at home, how water is brought to the desert, how ice-bound roads are opened, and how the breaking down of barriers the finding of means of communication, and of fields for work, etc., is going to affect the progress of mankind.

Methods of study in these later stages (as in all) will largely depend upon the ingenuity and personal power of the teacher. The writing of essays on such subjects as above indicated is a good way, helping the power of accurate thought and expression.

It is stimulating, too, for the pupils to be set economic problems to which they must search for the answers from any available sources, books, newspapers, magazines, and the like.

Regional geography so studied is valuable too (this has been mentioned before) as a means of gathering a good deal of useful "general knowledge" which does not seem to fall under other headings ; and just as method is dependent upon

the teacher, so also out of the many possible lines along which geography can be studied—physical, political, commercial, military, historical, etc.—the one followed in any given school will be decided by the qualifications of the teacher, the local conditions of the school, and most of all the requirements of the pupil. But however various such requirements may be, and whatever the special studies that each individual may attempt, we shall expect to find him, as he goes on, more and more conscious of the essential unity of all phenomena, and echoing Huxley's dictum that "to attain to even an elementary conception of what goes on in his own parish he must know something about the universe."

XI

SCIENCE IN THE TEACHING OF HISTORY

By F. M. POWICKE, M.A,

IF there is a methodical way of presenting scientific truths in nature to the growing mind, it is natural to suppose that there must be some similar way of presenting historical truth—an orthodoxy in historical teaching. Now, I take it for granted, on authority, that there is an orthodoxy in scientific teaching. The argument, presumably, runs something like this: "The subject-matter of my study, physics, chemistry, biology, or what not, is a series of laws, which form a coherent code. In teaching, I desire to give not only a knowledge of this code, but also a sense of its unity, its complexity, its fascinating inexorableness, its problems. There must be a right way and a wrong way of doing this. Here is the right way." The difficulty, if there is any difficulty, is not to prove that the laws of a science *are* laws, but to show what the laws mean and how they involve other laws, and

are intelligible, so far as anything can be intelligible.

It is at this point that I am asked to begin: "Take history, the story of men and their deeds on this earth, and say how one man or woman is to explain the story, so as to reveal the laws of human action, and the manner in which one deed follows from another, the change in society, and all the other things which form the subject-matter of your science." And this is just what most people who like history will refuse to do.

At first we (for all must share the responsibility) begin to wriggle. We say: "There is a very beautiful science which teaches how to get at the truth." This sounds promising. "This science is called by many names. You can by its means discover whether a document is forged or genuine; if it is genuine, you can find out whether some detail which it narrates, the date of a battle, the name of an official, etc., is likely to be true or not, and if likely to be true, to what extent." But by this time we are interrupted and informed that textual criticism or palæography are not usually taught in schools, and have nothing to do with the teaching of history there. That is not *quite* true, as we shall see; but let it pass.

The next objection is more subtle and really very hard to answer. We say boldly: "There are no laws in history. It is not a science at all. And, if it is not a science at all, there cannot be

a scientific way of teaching it; so there is an end of the matter." Now, ceasing to play the advocate, let us see if this is the end of the matter.

It is, of course, true that no amount of historical study can bring us to the discovery of a necessary framework upon which the story of man is woven in a fixed pattern. Many people believe that this is the case, but the reasons for their belief are theological reasons. Nor can any one be absolutely sure, apart from similar religious or moral influences in his conviction, that history reveals a steady progress towards a good society of good men. Yet our feelings upon this point are generally due in great part to historical study; we may not be quite certain, but simply as students of history, we may reasonably feel that there is a slow and steady advance towards what we call good. No teacher who has reverence for the mind of a boy or girl would force an "interpretation of history" upon his pupils; but he would none the less be eager to show them how one fact led on to another, simply because he would desire to encourage a process of thought: and if a boy begins to think a piece of history out, he cannot help regarding history itself as a process of thought. It will be many years before he is distracted by the philosophy which tells him to consider himself as the creator, to say: "These facts are meaningless, till I regard them." Now it is just here that scientific method may be said

to begin. There is no difficulty in making a boy feel that history is a chart of cause and effect; but there is great difficulty in showing him what the causes and effects really are. The difficulty is, I suppose, the opposite of the difficulty in natural science. There the facts to be explained are obvious. So far as they are present to the senses, they are as obvious to the child as to the teacher. The laws are hidden. The teacher of history, on the other hand, can express the relation of cause and effect at once. For example, very little intelligence is required to understand that the Papacy rested upon the laws and institutions of the Roman Empire, or that there is some connection between Henry III's Parliaments and those of to-day. I think we are tempted to waste a great deal of time in labouring these connections. The difficulty before the scientific teacher of history is in the description of the change, not in its explanation. Any one who has examined history papers knows this. They are full of the philosophy of history, or of picturesque nonsense, and the truth of the former is as unintelligent as is the falsity of the latter. When the boy or girl grows up and begins to read books like Maine's *Ancient Law*, or Guizot's *European Civilisation* (to name two favourite Oxford books), the effect is the well-known eighteenth-century essay, well written, in a way intelligent, true—and yet not historical. This is

why, in spite of his great learning, Professor Freeman never succeeded in making the Englishmen before the Norman Conquest real. He revelled in cause and effect and analogies, as a mathematician revels in a puzzle.

It may be urged at this point: "You are not speaking of scientific method after all, but of the need of some imaginative faculty." Certainly imagination is the everyday quality of the historian, just as a quick hand and ready eye are essential to the experimentalist in a laboratory. The historical imagination is more than boldness of thought. It is, as has been well said, an impulse stronger than prudence. "Our eyes are wakeful only for a little space; let us win for them a sight of the unpeopled world, South of the Sun?"[1] We are beginning to be satisfied again with the fairy tale of the nursery and the legends taught in the junior forms of schools, because they awaken this precious faculty. But I contend that a strict scientific method must control this faculty when history begins to be studied seriously in schools. In the first place, that process of thought to which I have referred must be encouraged as a presupposition of historical knowledge, providing easily understood processes of fact. In the second place, the terms of this process must be examined and presented to the

[1] See W. P. Ker, *The Philosophy of History* (Maclehose, 1s.), p. 14, where this is quoted.

mind, so that the process is controlled and corrected and given real meaning. This needs work, and scientific work.

A boy, let us say, is told that the Parliament of 1295 was a model Parliament. He appreciates without difficulty that it consisted of barons, clergy, knights, burgesses, selected or elected in somewhat different ways; he appreciates also the cause of their assembly, and their importance as the forerunner of the English Houses of Parliament. But he knows nothing about the Parliaments of Edward I if he knows only this. If his teacher can convey no impression to him of the position and nature of the several estates, the informality of the royal court, the procedure of petitioning, the composition of a shire court at the end of the thirteenth century, the wealth and influence of the Church, the meaning of a statute and of the Common Law, the theory of kingship, and so on—if, instead of the truth, he gives modern meanings to mediæval things, his general rule is unintelligible to him, and the history of the next three centuries will increase his confusion. If, on the other hand, the boy—well fed on romances and acquainted with castles, abbeys, weapons, or pictures of them—has been placed in the right attitude, the wonderful vision of the growth of Parliament will gradually break upon him, as naturally as the sight of Hereward or Drake in his earlier years.

This is a trite illustration. It is dull and obvious. I give it, because it shows that, without serious work on the part of the teacher, even the dull and obvious parts of English history cannot be taught. Maitland's introduction to the records of the Parliament held in 1307 must have been a revelation to many who had trodden the hard fog-bound track for years. But, of course, the value of scientific method in teaching history may be seen by more picturesque illustrations. A great deal of archæology is now taught in schools. I believe that there is a science of teaching young children how to make models and so on to show the transition from the flint to the lance and suit of mail, from the log cabin to White House. This is amusing, and I should fancy really useful if the teacher enters into the game. It would be very tedious to talk about it —the fun lies in doing it, and in leaving off when we are tired. Every teacher soon finds out how far he is fitted to teach in this way, or has a capacity for lecturing with the aid of a magic-lantern. The results of archæological research, however, may be made to have a deeper meaning for the schoolboy. They stir wonder, and wonder brings reflection, which, if well guided, may suggest some law, or rather custom, of development.

The value of history, for the child as for the man, is just that it provides illustration of truths

which become meaningless if they are left alone, as a god dies if it has no victims. We should start from the theory or the law—regarding it definitely as a thing of human contrivance, discovered or suggested by the same effort as any theory or law of natural science, but the beginning, rather than the goal, of enquiry. It is said that fifty years ago the vicar of Bradford-on-Avon, looking down from the top row of that hilly little town, noticed that the roofs of some cottages near the church concealed the form of some ecclesiastical building—and so he discovered the most perfect Saxon church in England. This is the crude beginning of scientific discovery, but is like any other in this—that we must start from the law. This fascinates a boy, just as he is fascinated by the knowledge that a zoologist can construct an extinct animal by studying a single bone. If he is taken to a ruin, and knows how a Cistercian abbey was built, he will speculate eagerly and intelligently about the meaning of the tumbled stones. This is better than essays about the place of monasticism in history (a subject upon which he is unable to form an opinion), and very much better than sentimental reconstructions of the monastic life; for the end is gained indirectly. The boy will speculate afterwards, if he is interested.

The teacher of natural science increases knowledge, the teacher of history shows the full-

ness of life. Both increase wonder, and both need the scientific method. Otherwise we know what happens.

> The dignities of plain occurrence then
> Were tasteless, and truth's golden mean, a point
> Where no sufficient pleasure could be found.

Hence men, like boys, seek vain explanations. Thus, for example, they treated Apollo as the personification of the sun; but more patient scholars, who came later, took Apollo as they found him before the days of the theologians; they treated him scientifically and seriously as a fact. They cannot trace his origin, but they see what he was in the great days of Greece, and the story of his influence illustrates one of the two great truths of life—the dependence of man—so that we know better what the old-fashioned Greek thought of the family, and the State, and nature. And this is history, and the only way to teach history is to know how it is discovered. No teacher of history can afford to be a dilettante, or to despise those sciences of which I spoke earlier, though of course there is no need for him to be an expert.

In order to show something of the impressiveness of history, some such method as the following might be adopted. Just as boys and girls are encouraged to read and hear stories when they are very young, so they ought to be encouraged

to read history as they grow older. But they should read it for themselves as a pastime—those who will not read it will seldom be really interested in historical teaching. Up to the last year or two of school life, I think that there should be no history teaching proper. Some dates and lists might be learned—the alphabet of the study—and children should be encouraged to talk and question and elaborate theories of their own. They ought to be made to feel that a great and important study lay in front of them—but nothing *serious* ought to be attempted. It is surely better that a boy should have read some Macaulay or Gibbon and have known nothing of what scientific historical study is before the age of sixteen or seventeen. I have listened to innumerable papers on how to teach history to young children, and they all seemed to me to be words. Then when the teaching does begin, it should be real. The teacher must know his work through and through. He should shirk nothing in the way of law and idea which arises out of his subject, because he has to test everything and train the mind of his pupils to be patient, interested in life rather than in drawing deductions from life, eager to get at the truth after trouble, like getting a fine view after a dull walk. There should be no hurry at school to fix and define the sequence of civilisation, but there should be great care to make the different stages *real* and living. The

test of success is that the boys and girls are keen on what happened—for they are in the stage of romance—before they are keen on why it happened. For then, after the inevitable period in which the intelligence deserts history for philosophy, it will return. This period generally comes in the first year or so of university life. It is inevitable, but only for the awakened intelligence.

There is one last anxious query, "What should we teach?" Here I am very bold. So long as it has some connection with what is known or interesting or compelling—whether it be the blue Mediterranean or the British Empire—let it be anything. For, if the first obvious law of cause and effect—the starting-point—be the guide, the subject is sure to be a big subject; and, if so, it will lead on and on. The teacher must know where it is leading, and ever keep it from getting too wild, and should prepare accordingly. But there is no hard and fast rule of companionship in history any more than there is in our present life.

XII

ECONOMIC SCIENCE IN SECONDARY SCHOOLS

By AUGUSTUS KAHN, M.A.

THE writer desires at once to disclaim any intention of advocating the addition of a new subject to the general curriculum. "Economics" is already in the curriculum, not indeed as a "science," but as "sums" to be done. By universal consent, "Interest," "Discount," "Stocks and Shares," "Profit and Loss," "Partnership," and "Exchange" are included in the arithmetic syllabus. The fact that we cling to these topics seems to indicate a sense of the incompleteness of a course of general education which would take no account of man's economic environment. Our pupils will later on in life have to earn and to spend; they will have to pay rates and taxes; they may wish to save and invest, and insure their lives. One might, indeed, go further and point out that the obligations of citizenship involve an intelligent grasp not only of municipal and national finance,

but also of the larger economic questions that enter into the sphere of practical politics. As a matter of experience, however, our pupils do not carry from their arithmetic lessons any very definite notions of stocks and shares. We ought not to expect it—we should not expect physics to be taught from arithmetical exercises.

Now if a subject with a new label is not to be entertained, it may, at any rate, be urged that the lessons in applied arithmetic should assume the character primarily of lessons in the economics of everyday life. Arithmetical applications in their proper place will both strengthen the economics and the arithmetic. There is no objection, of course, to the teacher of arithmetic continuing to give the lessons, provided only that he have the requisite knowledge of economics.

A sketch of a suggested course of lessons may, it is hoped, serve the main purpose of this article :—

I. *Interest.* (*a*) The productive nature of capital led up to by concrete cases, e.g.—A hawker invests 2s. in toys and sells them for 3s. His profit is 1s. This profit is due partly to his labour and partly to his capital—the part due to his capital is the *interest* on his capital. Again, a hawker of baked chestnuts buys 2s. worth of raw chestnuts, possesses an oven worth 5s. and coke worth 6d. He sells his chestnuts in the course of the day for 4s. He replaces the sold

chestnuts and 3d. worth of coke consumed, so as to put him into the position in which he started. In addition to his initial wealth he has 1s. 9d., which is the result of his labour and his capital. If 1s. is regarded as the remuneration of his labour, then 9d. is the interest on his capital of 7s. 6d. for one day.

(*b*) The term "interest" is used also in another sense. If A has a *claim* on B for £50 payable in three months' time, and transfers the claim to C for an immediate payment of £49 10s., then 10s. is the difference between the amount of the claim and its present value. This 10s. is called the interest on the present value for three months. Or suppose A lends B £100 for six months. B might, of course, use the £100 productively, but he might also "consume" the money. The purpose of the £100 is not enquired into by the lender. He gives up a present possession of £100 in return for a *claim* of £$100+x$ realisable after six months. The £x is the interest on £100 for six months.

II. *Money*. We give up things for gold, because with the gold we can procure other things. *Gold* is thus a *medium of exchange*. For the sake of convenience, the Mint makes pieces of gold of definite weight and of definite fineness. In fact, out of 40 lbs. troy of standard gold (i.e. gold of $\frac{11}{12}$ fineness), the Mint coins 1869 sovereigns. Arithmetical applications :—Out of 1 oz. troy of

standard gold are made 3·89375 sovereigns (=£3 17s. 10½d.). The weight of a sovereign is 123·27447 grains, or 7·98805 grammes.

The Mint coins gold free of charge; so that an ounce of uncoined gold would be the equivalent of an ounce of coined gold, were it not for the time (about two or three weeks) which it takes to coin the gold. It is found preferable, indeed, to sell bullion to the Bank of England at the minimum rate of £3 17s. 9d. per oz. of standard gold. An arithmetical application would compare the loss of interest entailed by utilising the Mint with the minimum loss of 1½d. occasioned by selling bullion to the Bank of England.

A melted *shilling* is by no means worth the twentieth part of a sovereign, as will easily appear from the quoted price of silver and the weight of the shilling. Yet twenty shillings exchange readily for a sovereign, because public confidence in their exchangeability is maintained by limiting the coinage of silver to the amount demanded for the purpose of small transactions. The exchangeability of bronze coins is similarly maintained.

A sovereign performs also the function of measuring the value of wealth; and by virtue of this function we dispense to an enormous extent with the use of gold as a medium of exchange.

III. The *banking system* enables payments to

be made by transference of "credit." If A has a current account with a bank, he may pay B by giving him a cheque (not exceeding the amount of his account) on his bank. Suppose firstly that B has a current account with the same bank. If he pays in this cheque to his account, the bank *debits* A with the amount and *credits* B with the amount. Suppose next that B has his current account with another bank. Then B may still pay in the cheque to his account, and if both banks are represented at the *Clearing House*, and have balances with the *Bank of England*, the Clearing House to which the cheque is sent will arrange for a transference of the amount of the cheque from the balance of A's bank with the Bank of England to the balance of B's bank. A's bank will debit A, and B's bank will credit B with the amount. Banks that are not represented at the Clearing House make use of banks which are so represented.

The use of the *bank-note* as a substitute for coin and the conditions of note issue will complete this topic.

IV. £1000 of bank-notes represent to the holder £1000 of wealth, although the notes constitute merely *claims*. A large portion of people's possessions are indeed made up of *claims*. Among such claims are stocks and shares. What is Government stock? An explanation of the issue of stock will lead up to

the meaning of Government stock as being a claim upon the Government to receive payments of definite amounts at definite periods, either perpetually, or, if for a certain number of years, with the additional claim to receive at the expiration of those years a definite principal sum. The periodic payments are regarded as interest on a nominal sum. If you buy £100 five per cent irredeemable stock of a particular State for £98, you are giving up £98 for the *claim* upon the state for a perpetual annuity of £5.

This claim is marketable just like wheat, and just as the price of wheat is continually changing, so the price of this claim is continually changing. [Here a digression on prices (with copious illustrations) as determined by the forces of supply and demand will be appropriate.] The price of the claim will, for instance, be influenced by additional borrowing (increasing the supply of "claims") and by saving (increasing the demand for "claims").

V. *Shares.*—In the first place, it would be desirable to consider the association of two or more persons as partners, and the sharing of profits (including interest on capital and remuneration for work done by the partners) in accordance with the partnership agreement. Profits, by the way, are not necessarily divided in proportion to the partners' contributions of capital, as they invariably are in arithmetical

textbooks. Next, the nature of a corporate body would be explained, and the *Limited Liability Company* as a particular form of a corporate body would receive full treatment. The order of topics would be: the formation of a limited liability company (in which the liability is limited by shares), the *Memorandum of Association*, the *Articles of Association*, the distinction between *authorised or nominal capital*, *subscribed capital*, and *paid-up capital*, the division of the "capital" into *shares* of various categories, the division of profits amongst the shareholders, the issue of *debentures*, the *transferability* and the *marketableness* of shares and debentures, and the variations of their prices.

Such a course of lessons with arithmetical applications may easily occupy two years (say from fifteen to seventeen years of age). The sketch is necessarily very brief, and deals only with the *matter* of instruction. Space does not permit of a discussion of method; but it will be apparent that the "method of discovery" (under the direction of the teacher) coupled with the "method of exposition" is applicable and appropriate.

A further question now arises, whether, in a curriculum specially adapted for boys preparing for commercial life, a more complete course of economic science should hold a prominent place. The "political economy" which is current in this

country does not indeed appear to bear very closely upon the problems of business life. The large majority of successful business men have never heard of Ricardo's Theory of Rent, and they have never troubled about the philosophical niceties surrounding the meaning of wealth and capital. They have, however, had economic problems to solve. But there are also the many failures, there is an army of commercial assistants who perform their work mechanically, unintelligently, and without interest, for whom "experience" is unfruitful because they have not been taught to observe and to think. A preparation then at school—*if it can be given*—which shall help the pupil later on to realise the nature of his work, to observe the problems which lie before him, and to place himself in the right attitude towards his environment must assuredly be justified. Commerce, it is true, embraces a large variety of occupations, but they fall into a few groups; and even *retail* trading (based largely on psychology) has economic problems in common with other branches of trade. It is moreover the business of scientific preparation rather to widen than to narrow the outlook.

Now the actual proof of the suitability and the value of a course of economic science must be furnished by experiment; and in order to make out a *prima facie* case for experiment, the writer will attempt to indicate the treatment of one or two

economic questions in the class-room of boys of, say, seventeen years of age. Let us take the quite ordinary commercial question of the relation of *turnover* to *profits*. A synopsis of the lessons would be as follows :—

What are the profits of a trader who buys goods for £x and sells them for £y? What is the actual addition to his wealth in consequence of this operation? Gross profits and net profits. Net profits = (selling price) — (cost price) — (working expenses).

If he sells n articles in a year at s per article, and if the cost price is c per article, then net profits = $n(s-c)$ — (working expenses). Let working expenses be firstly proportional, and secondly less than proportional to the number of articles sold; how do net profits vary with the number of articles sold? If selling price is reduced to s', what must be the increase in the number of articles sold, in order that the net profits may not be diminished, assuming no change in the working expenses? Applications: Suitability of position with due regard to rent, the value of goodwill, multiple shops, department stores, tendency to retail distribution on a large scale.

As a further example, let us take a lesson on the effect of various operations on the balance sheets of the Issue Department and the Banking Department of the Bank of England :—

ISSUE DEPARTMENT.

Liabilities.	£	*Assets.*	£
Notes issued .		Government Debt and other Securities . . .	18,450,000
		Coin and Bullion	

BANKING DEPARTMENT.

Liabilities.	£	*Assets.*	£
Proprietors' Capital . .	14,553,000	Government Securities .	
Rest . .		Other Securities	
Public Deposits		Reserve { Notes	
Other Deposits .		Reserve { Coin .	
Seven Day, etc., Bills			

(*a*) The effect of discounting a bill of exchange: Bills of exchange are included in "Other Securities." These therefore increase. Suppose that the Bank pays by cheque: "Other Deposits" increase. The "Reserve" is unchanged. The ratio of "Reserve" to "Deposits" is therefore diminished.

(*b*) The effect of selling Consols—"Government Securities" are decreased; if payment is made by cheque, "Other Deposits" are decreased; therefore ratio of "Reserve" to "Deposits" is increased.

(*c*) The effect of the withdrawal of cash by depositors: "Reserve" is decreased and "De-

posits" are decreased by the same amount. How is the ratio "Reserve" and "Deposits" affected?

These notes of lessons are intended to indicate both content and method. We must offer our pupils not abstract theory or speculation, but matter that is concrete and definite; and we must present not chapters of a textbook to be "got up," but a series of problems to be solved.

The syllabus of such a course of economic science would be on the following lines:—

1. *Classification of Occupations.*—Industry, commerce, transport, the performance of direct services. Subdivisions.
2. *Labour and its remuneration. Capital and its remuneration.*
3. *The Organisation and Administration of Business Enterprise.*—Partnership, limited liability companies.
4. *Money and the Banking System.*—The English system of currency, the Bank of England and its relation to the banks, "credit" as a substitute for coins, the money market, some foreign systems of currency, parity of exchange, the bill of exchange, methods of payment, rates of exchange.
5. *The Retail Trade.*—Fluctuation of prices, turnover and profits, tendency towards retail distribution on a large scale.

6. *The Wholesale Home Trade.*—The commercial aspect of industry, the intermediary between the manufacturer and the retailer, fluctuation of prices.
7. *Foreign Trade and its Machinery.*—Marine insurance, documents of title to goods, fluctuations of prices of (*a*) raw produce, (*b*) manufactured goods; the settling of international indebtedness.
8. *The Stock Exchange.*
9. *The Principles of Taxation.*—Loans and their amortisation.

XIII

DOMESTIC SCIENCE

By ARTHUR SMITHELLS, F.R.S.

AMONG the many new movements in the educational world there are signs of an increasing disposition to give to girls of all classes some systematic teaching and training in matters relating to the management of a home. Instruction in the household arts, such as cooking, laundry work, and sewing, has for a considerable time past been given in the public elementary schools. The provision of such instruction in secondary schools is of more recent origin. It usually follows the ordinary school course, and is regarded as a supplementary training for girls whose taste, capacity, or means do not lead to their passing to a place of higher education. In a few schools the courses are part of the ordinary curriculum and constitute a sort of modern side.

The term domestic science has been used rather loosely, and is often applied to subjects and to a kind of teaching which have nothing in them to which the word science or scientific

would ordinarily be applied. It will be convenient to make a distinction between domestic arts and domestic science, not with a view of exalting one above the other, but for the sake of clearness.

It is not the object of this article to discuss the teaching of the domestic arts, but a few words may be devoted to the subject. The notion still generally prevails that housewifery, which may be regarded as a collective term for the domestic arts, is, and should be, learned by the time-honoured system of apprenticeship, that is to say, a girl should in the ordinary course of things learn it in her own home. There is, however, abundant evidence to show that this apprenticeship is often of a very haphazard character and very ineffective, and that there is room for courses of systematic instruction to be conducted by teachers who have made themselves specially competent for the work. No one will doubt the utility to a girl of the practical proficiency which results from such teaching, but many will doubt whether there is much purely educational value in it. Here, as in all other teaching, the educational effect depends on the teacher rather than the subject. There is little doubt that a woman with cultivated intelligence, the gift of teaching, and the all-important element of personality can obtain excellent educational effect from teaching the domestic arts,

even if she have little or no knowledge of science. The inculcation of neat and cleanly manipulation, of systematic habits of work, of resourcefulness, of the adjustment of means to ends, of thrift,—this is surely of eminent educational value in the broad and vital sense of the term. The habits of attention and thoughtfulness, it is found, may often be induced by means of this teaching to such a degree that girls will return with a greatly improved attitude of mind to more abstract studies which have previously failed to gain any hold upon them.

It is, however, the case that the whole business of housewifery is involved with science and the application of scientific principles, and there does indeed exist a very large section of knowledge which may be called domestic science. This is not self-contained, but includes the application of physics, chemistry, and biology, and perhaps other sciences.

There is a great tendency throughout education for the maintenance of an academic convention, in accordance with which subjects are taught in a formal, abstract, and isolated manner as so many chapters of knowledge. The possessor, it is supposed, will learn to make the application which may be necessary in his or her particular calling. Experience shows that this kind of knowledge is, as a matter of fact, apt to remain permanently detached, for the simple reason that it is not at all

easy to make the application, and that there lies between general principles and the ordinary things and pursuits of life a great body of intermediate knowledge which needs careful disclosing and expounding.

These remarks certainly apply to the science teaching which has long been customary in schools. It may have been given in such a way as to have conveyed a good knowledge of principles and facts and to have induced the scientific habit of mind, yet it may have left no obvious links for its attachment to practical affairs. To give a simple example,—a man may have learnt a great deal about heat and chemistry and be quite baffled when asked to explain why a plumber uses rosin in soldering and how it is that solder remains pasty while he wipes a joint with it. The household abounds in examples of this kind. Questions relating to the quality and uses of fuel, the construction of burners, lamps, grates, the nature of detergents and the explanation of their action, paints, lacquers, sizes, polishing agents, and a hundred other things—on these, pupils who have "done" a good deal of science, and too often their teachers also, may be in a state of profound ignorance and quite unable to help themselves to knowledge. It is not easy for any one who has not given a good deal of thought to the subject and has not been questioned by classes of eager housewifery teachers

to form an idea of the number, variety, and difficulty of the scientific questions that arise in the commonest household matters.

The practical value of a knowledge of the science connected with the household is undeniable. In relation to hygiene it is particularly obvious, for here the method of learning by making mistakes is perilous. A knowledge of the scientific basis of hygiene, involving a revelation of the connection between cause and effect, is infinitely more persuasive to hygienic practice than any amount of precept or admonition. When people can say "I *see* I must do this and must not do that," they are in a totally different attitude from those who say "I am *told*." In this and other household matters let any one observe how frequently practice is determined by the vague sanction of "they say." In no other sphere of human activity is individual knowledge and judgment so complacently resigned in favour of drifting tradition and nebulous authority.

Those who declare that women will become more fit for their work by learning science meet with a good deal of banter, and facetious remarks are often made about scientific cookery. Let us admit at once that a good *chef* is not a product of science and perhaps cannot be equalled in his art. At the same time any one who has taken the trouble to look into the matter will see what a vast amount of trouble and error may be saved

even in cookery by the application of scientific knowledge and by the scientific attitude of mind. The fact is that the household abounds with the operations of applied science and it is therefore *prima facie* probable that a knowledge of this science will lead to greater efficiency. Apart, however, from all this, a good end will be achieved if the work of the household is made more interesting to those who pursue or control it. There are some people—perhaps many—who are perfectly content to work away at a daily routine and ask no more than that their service shall be directed to some good end. But there are many others—especially those who have a sharper mental appetite—who crave for intellectual light to illuminate their activity and cheer them on their way. It is surely incumbent upon us to provide what we can of intellectual interest to accompany the exacting work of the household, and for this reason, if for no other, we may bring as much scientific knowledge as we can into the domain of the housewife.

Science teaching can be of no real value if it does not impart the scientific habit of mind and give the pupil a knowledge of scientific principles, and it cannot do this unless it is experimental. In many past attempts to teach a domestic science these primary facts have been neglected. There has been, for example, a good deal of hygiene teaching which has consisted in making pupils

remember an assortment of scientific facts dictated to them by the teacher, sometimes without any kind of experimental illustration. The outcome of this kind of teaching of hygiene and of the science of cookery or laundry work has been worse than valueless. It is, however, a great mistake to suppose that the teaching of facts relating to hygiene and other household matters is inconsistent with the inculcation of sound science, and it is the chief object of this article to plead for a *via media* between purely academic science and the medley of bald information which sometimes passes by the name of household science.

It is possible to teach the principles of physics and chemistry from many points of view. We teach them in their relation to facts and phenomena, but the facts and phenomena that illustrate these principles and can be made the basis of experimental teaching are so numerous that we must make a selection. Inasmuch as interest is the first thing to be secured from our pupils, we shall do wisely to go as far as we can to choose our ground where the interests of our pupils lie, and in the case of girls the realm of housewifery gives us what we want. There is hardly a pupil who has learnt anything about heat who has not had his attention drawn to the circulation of water during the freezing of a lake, yet it is only quite recently that girls have ever been given a

notion of the circulation of water between the cistern, boiler, and cylinder in an ordinary hot-water system. It is very easy to make a working model of such a system out of ordinary laboratory apparatus, and so to provide an excellent experimental appliance for studying many of the fundamental principles and facts relating to heat. Experiments with thick and thin, deep and shallow pans, pans made of different metals, pans containing liquids of different viscidity and boiling-point; experiments on evaporation, steaming, and freezing—these can all be made perfectly scientific, and yet abounding in useful information from the kitchen standpoint. In chemistry too it is not difficult to bring the teaching into close relation with things and phenomena of the household. The subject of combustion, which is so central and fundamental, may be made to involve the action of heat on metals, the study of coal and coal gas, and the appliances connected therewith.

It is quite true that there are a great many household things on which elementary science will tell very little. The chemistry of food and cookery is a very abstruse subject, and it is useless from every point of view to burden pupils with lore about albumens, globulins, caseinogens, and the other terms which oftener serve to conceal ignorance than to display real knowledge. Yet such changes as fermentation by yeast can

be made an excellent basis of experiment, and in this particular case will serve to give some real apprehension of the facts of bacteriology. The story of Pasteur's life and work, accompanied by a few simple experiments, including a census of the germs in the air of the schoolroom, makes as impressive and valuable a lesson in scientific method and gives knowledge of as vital importance as anything within the realm of science.

Enough, perhaps, has been said to give an idea of the trend of what might be fairly called domestic science. An admirable syllabus of such a course drawn up by Mr. Heller will be found appended to a report presented last year to the Education Section of the British Association, and from this teachers who are disposed to turn their attention to the subject will get the best idea of the way in which they may set to work. In this, as in all other educational innovations, tradition, codes, examinations, and the desire of overworked or half-hearted teachers for ready-made schemes are the chief obstacle to success. As already stated, a considerable number of girls' schools have already entered upon the work and, so far as can be judged, the result has been to give a greatly increased interest and value to their science teaching.

XIV

THE TEACHING OF CHEMISTRY IN TECHNICAL SCHOOLS[1]

BY HENRY GARRETT, B.Sc., Ph.D.

CHEMISTRY is at present taught at the university, the secondary school, and the technical school, but it does not follow that the aim of the instruction in all three institutions is the same, or that the methods of teaching should be alike.

In the university the object is to give students a somewhat detailed survey of the facts in so far as they are known and of the theories by which they are linked together and explained. The university student acquires knowledge for its own sake and investigates truth without special regard to practical applications. All knowledge is, no doubt, useful, potentially at least, but all knowledge is not equally useful, and one of the chief functions of the teacher of technical classes is to discriminate between the useful and the academic.

[1] In this and the following two papers on technical aspects of science teaching it has seemed convenient to deal with work partly outside the sphere of ordinary secondary education, but concerned with students mainly of secondary-school age.—ED.

In the secondary school the object is not so much to teach chemistry as to use the subject for the cultivation of observation, reasoning power, and systematic habits. Thus the aim is distinct from that of the university and the method employed different.

It remains to show how the object of the technical school differs from either of the above and what means may best be taken to secure that object. In order to arrive at a satisfactory conclusion, several factors must be taken into account. It is necessary to consider who the students are, why they attend, and what time they may reasonably be expected to devote to the subject.

With regard to the first point, it will generally be found that the students may be roughly divided into three groups:—

(*a*) Industrial Students: viz. those engaged in industries of a distinctly chemical nature, such as analysts, pharmaceutical chemists, gas workers, bleachers, dyers, distillers, mineral-water manufacturers, vitriol manufacturers, artificial-manure workers, soap manufacturers, and employees in chemical and electro-chemical works.

(*b*) Teachers of primary or secondary schools and university students.

(*c*) Artisan Students: viz. those engaged in occupations not distinctly chemical in nature,

but in which some knowledge of chemistry is desirable, such as builders, plumbers, and decorators.

It will be readily granted that these three groups of students have different objects in view. They have, however, this much in common, that they all attend in order to fit themselves better for the work in which they are engaged. Attendance being entirely voluntary, it would be vain to expect continued attendance from a student who felt that he was not obtaining what he came for, or was being led to the desired goal by an unnecessarily roundabout path. It cannot be too strongly emphasised that examination certificates, while of considerable value for intending teachers, are of little or no value to the industrial or artisan student. Moreover, the attempt to prepare for examinations often leads to the neglect of what is most useful for the student, and to the consideration of unessential matter necessary for the examination. The evening technical school is by no means the best training-ground for teachers, and it would be a fatal mistake to arrange the course of work to suit the needs of teachers when such a course is unsuited to the needs of industrial students. In so far, however, as the teachers can derive benefit by attending classes arranged for industrial students there can be little objection to their doing so, but when their numbers are sufficient they are best catered for by special classes.

The main point to be borne in mind is that the interests of the more properly technical students should not be sacrificed to those of the teachers, who can be much better provided for otherwise.

To the second question—why students take chemistry—the answer will be different for the three types of student mentioned. The industrial student requires a wider and deeper knowledge of the application of chemistry to industry. The teacher desires further knowledge and additional qualifications for his professional work. The artisan student needs a course of a limited and special character to enable him to deal intelligently with the materials he uses. The industrial and artisan groups require separate treatment if for no other reason than that the time which they can give to the study differs widely. With the one chemistry, in its various branches, is a special course of study, with the other it is a subsidiary subject and should be treated as such.

The third factor in the problem is the time at the disposal of the student. The special course for chemical industries usually extends over four years, and this time will seldom be exceeded. It is thus necessary that the industrial student should have a course drawn up for him on the assumption that he can attend from four to five hours per week for four years. In other words, this course must provide for his wants in a period of about 500 hours' instruction. It will be evident that

such students cannot afford much time for the consideration of facts or theories which have little practical bearing, nor can they follow a purely educational course of the secondary-school type. A suitable course will aim not only at giving the student a sound knowledge of the chief facts and principles of chemistry in so far as they are of practical utility and a special knowledge of the chemistry bearing directly upon his industry, but will also teach him how to solve by experiment difficulties arising in the course of his daily work.

The syllabuses usually followed at present are arranged on the assumption that a student can give at least one evening per week for five years to inorganic chemistry alone. Since also a student could not profitably begin organic chemistry in his first year of specialisation, he is required to devote a second evening per week to this subject in the last four of these five years. There are two strong objections to this arrangement. The first is that the course not only uses up all the time presupposed above, but makes a further demand of a fifth session, and this without allowing any time for attendance at special classes dealing with those branches of the subject in which the student is more particularly interested. A second and even weightier reason against the present arrangement is that the syllabuses followed are of an academic character. Applied chemistry occupies an altogether subordinate

position, manufacturing processes are generally not reached until the third year, and a very large portion of the available time is spent upon test-tubing and analysis. Qualitative analysis may or may not form part of the requisite course for an industrial student, but for the majority a limited amount should suffice. A special class dealing exclusively with the subject will, however, be found necessary in large institutions to provide for analysts and those whose work bears in that direction.

These remarks tend to show that the present courses are too ambitious in the direction of theoretical and analytical chemistry, and experience demonstrates that if industrial students are to be really catered for considerable modifications in our present system are necessary. These must go in the direction of reducing the time devoted to inorganic and organic chemistry so that this portion of the work may be covered in one evening of two and a half to three hours per week for four years. Further, the treatment of the subject must be modified and an effort made to study it in connection with its practical applications.

It may possibly be urged that applied chemistry cannot be studied with advantage until the student has a fairly comprehensive knowledge of pure chemistry. If we apply the same reasoning to other subjects, such as mathematics, its absurdity will be at once evident. The student of practical

mathematics would be in sad case if he were unable to take up his special work until he had completed the study of pure mathematics. There is no adequate reason why chemistry should not be studied from the very beginning in connection with its industrial applications. Nor should it be forgotten that the student under consideration is more familiar with certain applications, at least, than with underlying principles. Educationally, therefore, the procedure advocated, viz. from the familiar to the unfamiliar, is sound.

An attempt will now be made to indicate an arrangement of subjects for industrial students which it is considered will be likely to lead to good results. These courses are intended for earnest students who are willing and able to devote two evenings per week to the requisite study spread over a period of four years.

> In the first year, students would be well advised to take physics or mathematics in addition to chemistry.
>
> In the second year of specialisation they should continue inorganic chemistry and take in addition a special class suitable to their occupation, such as technical analysis, chemical engineering, bleaching and dyeing, gas manufacture, or acid and alkali manufacture.
>
> In the third year they should take organic chemistry and one of the special classes already mentioned, or certain new classes suited to the

needs of the district, such as the chemistry of foods, paper manufacture, electro-chemistry, etc., or a second stage of such larger subjects as bleaching and dyeing and technical analysis.

In the fourth year a treatment of the benzene derivatives should be undertaken and the other elements of a course made up from the subjects already mentioned.

Needless to say, the organisation here outlined is only possible in a large institution, but even where the staff is limited, sound and useful work may be done by not attempting more than two or three years of the course and sending on advanced students to a larger institution. The underlying idea is that a chemistry class should be taken in each year, together with one or more classes of a special character.

In the central chemistry class the treatment of the subject should involve at every point a consideration of the application of laboratory methods to industrial practice. Such a course might naturally begin with a description of the mechanical processes used in chemistry—filtration, distillation, decantation, evaporation, crystallisation, etc. These descriptions should show not only the methods used in the laboratory, but also the principal modifications of those used in chemical engineering. The lectures should be illustrated by experiments and by slides showing the plant used for industrial purposes, while the

laboratory work would take the form of practical exercises illustrating the processes dealt with. Following upon this work might come a consideration of oxidation and combustion. This part of the subject would be illustrated by numerous exercises on the rusting of iron, the oxidation of metals, phosphorus, carbon, etc., on heating, leading to an examination of the Bunsen burner with its many applications—incandescent mantles, blowpipe, oxyhydrogen blowpipe, and oxyacetylene blowpipe. The importance of the subject of high temperatures is so great from an industrial point of view that it will be well at this stage to consider as fully as possible the chemical means at our disposal of obtaining high temperatures. Incidentally, the chief constituents of the atmosphere will receive consideration and a study of oxygen be undertaken. To complete this branch of the work electrical methods of heating will require attention. The converse process of reduction of oxides by hydrogen or coal gas will provide much useful information, while the use of carbon for the same purpose in metallurgical processes, such as the extraction of zinc and iron from their ores, as well as the numerous reductions in the electric oven, will open a wide field for investigation.

Next in importance to heat as an agent in producing chemical change come probably the common acids. Their physical and chemical

properties should be carefully studied, as well as their methods of manufacture. It might be well at this point to introduce a description of some of the more important contact actions, such as the platinum method of manufacturing sulphuric acid, as these actions are rapidly becoming highly useful commercially. Following upon such work will naturally come the large class of double decompositions, which take place when certain substances are heated together, or when solutions are mixed together. The way is also open for an examination of the alkalis and their reactions, in particular their power of neutralising acids.

It is not proposed to carry such a course further here. Sufficient has been said to indicate the general line which it may take. It may be urged that a thorough knowledge of chemistry cannot be had without close attention to chemical hypotheses, but while certain theoretical considerations are necessary for a clear understanding of the process studied, many others are of purely academic interest and may well be omitted.

The practical work of the classes should keep closely in touch with that done in the lecture-room, and the exercises should be designed to amplify and intensify the impressions there made.

Artisan students may be catered for in two ways. A short series of lessons on the chemistry of the materials which the artisan makes use of

may be incorporated into his course of building construction, plumbing, or painter's work, as the case may be. These lessons should be largely demonstrational and should deal with the chemical properties and reactions of building materials or of common metals, but they may also with advantage involve simple practical exercises.

Such a series of lessons need not extend over more than half a session, the other half being devoted to the necessary physics. Where separate teachers are engaged for chemistry and physics it should not be difficult to arrange for simultaneous courses for builders and plumbers or painters, the teachers interchanging classes at half-term.

An alternative method would be possible in cases where the entries for a preparatory course are sufficiently large to admit of the segregation of members of particular trades into separate classes. In such cases the science teaching of the preparatory course should take the form above outlined.

The greatest difficulty will be experienced by small schools where chemistry classes are composed of students of a mixed type; but, by limiting the course to the elementary stages, and by studying the needs of the class, teachers can do much to rescue the subject from its present marked theoretical and academic rut and to make it full of interest and usefulness.

XV

HOW THE SCHOOL MAY HELP AGRICULTURE

BY E. W. READ, M.A.

"PRACTICE with Science" is the motto of the Royal Agricultural Society of England, and gallant have been the attempts of this and the sister society of Scotland to bring home to the agriculturist the importance of science to him, while in Ireland the Department of Agriculture and Technical Instruction has been working miracles in recent years.

The splendid work of the agricultural colleges, often done under great difficulties, and in the face of opposition, has made its influence felt all over the country, and it is confidently expected that the next generation will see the great industry of agriculture established on a scientific basis. There are, however, many whose occupations are directly connected with agriculture who are doubtful of the value of science, though a very slight examination into the methods adopted by a successful farmer suffices to show that he

is in the true sense a man of science. No doubt he will tell you that an ounce of practice is worth a pound (or a ton) of theory, meaning that the results of his own and his forbears' experiences as to the best seasons for sowing and reaping and the rules to be observed in breeding and feeding stock are more likely to give him a balance at the bank than any amount of lectures or reading.

In other words, keen observation and many failures have taught him what not to do—how to get at the truth. This is *science.* The student of pure science, however, wishes to get at the truth, and does not mind the cost in time and money, whereas the farmer must make most of his experiments pay. One would think that the farmer would be very grateful to the scientist who is willing to assist in reducing the chances of failure, but it must be admitted that in Britain we have not yet found the true relationship between agricultural practice and science. It will only be found when education of the right kind is provided for the coming generation of farmers.

The recognition of the value of science by the farmer has been delayed through the action of people who, having a slight knowledge of chemistry, biology, or geology, or having visited other lands and seen one side of the methods adopted there, essay to teach him how to double his income. The weather, the district, labour, freights, taxes are nothing to these people, and

the farmer blames *science* generally, instead of *the want of practice.*

Again, the reputation of *education* has suffered, and in the eyes of the farmer the child is being spoiled. The fact is that the education given in country schools in Britain at the present time is not calculated to increase the child's respect for rural life. Too much is made of the academic side, and by the time the age of fourteen is reached, the boy is out of touch with all kinds of manual work, and the girl, though she may find it necessary to go into service, has no ambition to make herself a good housekeeper. If the advantages of town life to the people themselves and to the nation were beyond dispute, nothing need be said; but it seems unwise to encourage young folks to go to towns, where they will jostle for a pittance, and then to suggest that those out of work should go back to the land.

Educational authorities are partly responsible, as until quite recently they allowed, and perhaps indirectly encouraged, country schools to follow the lead of the town schools, and thus it has come about that the term "lad of parts" can only be applied to the boy who is "good at his books."

This paper is to deal with the education of the future small farmer and the agricultural labourer, leaving the large farmer to take care of himself. Many attempts have been made in Great Britain

and Ireland to provide in special schools a form of education which would assist the farmer to cope with changing conditions, but they have only affected a fraction of those concerned in agriculture. Farmers themselves are to a great extent to blame for this, as they have certainly received obviously genuine efforts with coldness, and even experimental farms have met with active opposition. To argue that they know what they want and should be left alone to work out their own salvation might be well enough if it concerned farmers themselves only; but it is, in fact, a national affair, and we must not allow other countries to outdistance us in the matter of agricultural education.

It is not suggested that the qualities which go to make a successful farmer can be got in the class-room, or in the laboratory, or by reading. He must be a man of character; possessing initiative; able to manage workmen; be a good judge of stock—know the right kind of store animals for his district, know when they are doing well and how to change pastures when they are not; he must be a good marketer, and know the true value of his fat stock and grain as well as does the dealer; and he must be a business man. Education cannot save the farmer if he does not possess these qualities, but it can help the boy, by widening his outlook, by encouraging him to take a pride in his occupation and a

pleasure in manual work, by developing initiative and observational powers, and by calling his attention to the necessity for cultivating to the highest extent the qualities mentioned above.

The spirit of the farm must be retained in the child, and afterwards he must have scope for his abilities. The labourer must be encouraged to take an interest in the work of the farm, and he will do so if he knows that he may one day have a small holding, and has confidence that he will be able to manage it.

Having indicated the results to be aimed at, the next thing is to show how they might be attained. We cannot look for assistance to the ordinary agricultural schools or to the agricultural sides of certain secondary schools. They do good work in the preliminary education of the larger farmer, the agricultural lecturer, and those concerned in estate management, but we want to get lower down and to influence a much greater number.

Can, then, the elementary schools or the higher grade departments of the public schools in Scotland help? Certainly they might do so; but they have become so imbued with the academic spirit that the spirit of the farm is neutralised and the pupil of fourteen has developed into a young scholar instead of being a young farmer at heart. In recent years these schools have certainly tried to meet the require-

ments of the country boy by giving some attention to nature-study, and in some counties by making the arithmetic of a more practical nature; but they must go much further than this or we must have special schools. In all probability it will be found necessary to provide such special schools for boys of twelve, at which they could follow a two or three years' course, the object of which should be to benefit directly the small farmer and the labourer. The country boy, it must be remembered, should have special treatment: he needs a form of education entirely different from that given to the town boy.

The teachers in these schools must be trained specially for the work, and they must be in entire sympathy with their surroundings. They must be as much farmers as teachers. They need not be university men; in fact, it would be better if they were not, unless they had worked on a farm for two or three years after attending at an agricultural college for two years. Eventually agricultural teachers' training colleges would have to be instituted, and these might be in connection with the agricultural college experimental farms.

The teachers would aim at producing good farmers, foresters, or gardeners rather than examination-passing machines. The farm-schools would not necessarily cost a great deal for upkeep, as the pupils would do much of the work

in connection with them. The question of cost, however, would have to be faced; and as it has been faced in other countries, there is surely no good reason why we should find it an insuperable difficulty. It seems as if these other countries are building up a business and spare no pains to push their wares, while Great Britain rests content with the idea that she runs (or did run) a paying concern, and will not believe that it is necessary to go to any expense to hold her own in the competition.

Now as to the curriculum of our farm-school. English, with history and geography, would occupy a very important position, as would mathematics and elementary science; and a considerable amount of time should be given to manual instruction and natural history.

Under the term natural history would be included botany, zoology, and geology as applied to farming, gardening, and forestry; work in the gardens and on the farm; the care of horses, cattle, sheep, pigs, fowls, bees, etc.; expeditions in the woods or on the hills; visits to larger farms or to experimental farms; the study of agricultural experiments, and meteorological observations.

The object of the work on the farm would be not so much to teach operations as to keep the boys in touch with farm ways and to provide subjects for discussion in the class-room. The

farm need not be large, but there should be a large garden, which, of course, the boys could lay out in the first place.

The elementary science should be correlated with the natural history, the substances used for experiments being, as far as possible, those which are of special interest to the farmer.

The manual instruction would primarily be educational, but in the third year the boy might learn to make modern fowl-houses and bee-hives, troughs, etc., put up and repair fences, and study farm machinery. This is not the place to enter into details with regard to English and mathematics, but so far from their being neglected they would receive more attention than they get in many secondary schools. It will be seen that in such a school the future forester and the future gardener might well receive part of their education.

Next, what happens to the boy when he leaves? He is, say, fifteen years of age, is not afraid of manual work, is trustworthy and possesses initiative, is ambitious to excel in some occupation connected with the country, and is anxious to learn more about his future work. If his father is a farmer he might go home; he might take up forestry or gardening; or he might be apprenticed to a farmer. How this is to be brought about is beyond the scope of this paper, but it is the opinion of the writer that with the co-

operation of farmers it is quite possible, and that the farmer himself would find one or two apprentices of this type a great acquisition in these days when conscientious workmen are comparatively scarce. Of course at this stage the boy would attend evening classes where possible, and he would still be under the eye of the authority which managed the school. In Scotland the authority would probably be a School Board (under the Scotch Education Department working in conjunction with an agricultural college), which would under ordinary circumstances interest itself in the boy's career until he is seventeen. In England conditions are somewhat different, and perhaps the County Councils would co-operate with the Board of Agriculture and work out schemes suitable to the needs of the various districts. Whatever the authority may be, it is hoped that it will study the special needs of the different districts and see that State aid is given without tying down all the schools to a particular curriculum. There must be an agreement between the authorities and the agriculturist as to the ideal to be aimed at, and they must take care that the school is run for the sake of the boy as a future farmer and a valuable asset of the State, and that it is not neglected because its value cannot be appraised by means of examination results.

Nothing has been said in this article about

the education of the country girl—not because its importance is overlooked, but because it is so important that it deserves a paper to itself. The chances of success of the small farm are doubled if the mistress is a good manager and takes an active interest in dairying, poultry-keeping, and gardening.

XVI

ENGINEERING

By AN ASSOCIATE OF THE INSTITUTION OF CIVIL ENGINEERS

IN attempting to deal with the sort of education that should be given to future engineers during their time at school, one feels at once the need of subdividing into classes. At one extreme we have the boy who will go to the public school and university, and finally take a position among what we may call the "directing classes" of the country; at the other extreme there is the boy who spends the years between thirteen and sixteen—when he enters works as apprentice—as a wage-earner.

The following division into classes will serve our purpose:—

<table>
<tr><th>A</th><th colspan="2">B</th></tr>
<tr><td rowspan="3">Those taking a full Secondary School Course and (probably) University Course in addition.</td><td colspan="2">Those not taking a University Course, including—</td></tr>
<tr><td>I</td><td>II</td></tr>
<tr><td>Those who, after attending an elementary school, receive some secondary education up to about sixteen years.</td><td>Those who leave the elementary school at thirteen or fourteen, and do not attend a secondary school.</td></tr>
</table>

We shall take Group II first. The would-be engineers who fall under Group II are somewhat difficult to deal with. The type of boy who is intended for an engineer varies so much in different parts of the country. The parents of such boys are generally artisans or are employed in commercial offices; and the five or six shillings a week which such a boy may earn in some temporary position is in some cases an important item in the weekly house-budget; and in other cases, although the sum earned is not necessary, yet the parents prefer to consider slight additional comforts rather than the prospects of the boy. Group II may thus be divided into two sub-groups:—

II*a*. Those who are given the opportunity of staying at school until they are old enough to enter the shops.

II*b*. Those who are sent to earn money as messengers, errand-boys, etc., from thirteen or fourteen to sixteen years of age.

With regard to II*b*: The boy at the age of thirteen, recently freed from the sometimes dull monotony of an elementary school, and with a sense of importance in that he is earning an income, is not inclined to continue his studies in the evenings (probably the only time available). Again, should he be working in a factory—making cardboard boxes, or occupied in one of the other hundred ways in which cheap labour

can be utilised—he may be at any time called upon to work late; and so, should he put down his name for classes, his attendance is likely to be irregular, in which case his interest in the matter will naturally dwindle. There can be little doubt among those who have dealt with apprentices and young workmen engaged in the shops, that those who belong to this section make a bad start; and that the three important years between thirteen and sixteen should *not* be spent in casual employment but in continuing the boy's education.

This naturally leads us to consider the section II*a*, and to enquire what courses lie open to boys when the elementary school has been passed through. Putting aside the secondary school, which we shall consider under I, the choice lies between higher elementary schools and pre-apprentice schools.

Should the boy enter a school of the former sort, he will attend a course of which the syllabus covers not more than three years—a course probably of a general character, without bias towards engineering. It is, indeed, stated somewhere that the course may be especially directed to train students for a local industry; but the atmosphere of the elementary school is often present, and the teachers unsuited to give such particular instruction.

The other course is to enter a pre-apprentice

school—a school sometimes called by other names, such as "Trade School," "Preparatory Trade School," "Junior Technical School." This type has only in the last few years taken a recognised place among our educational institutions; and papers of much interest on this subject will be found in a recent work edited by Prof. Sadler.[1]

We shall discuss, in some detail, the curricula of such schools for engineers[2]—feeling as we do that such schools are not so well known as are those of higher elementary or secondary type.

Perhaps the most important subject in the curriculum is English—the standard of English among the boys we are considering is notoriously low. Mathematics must have much attention; drawing—freehand, geometrical, and scale—claims an undoubted place. Practical work, both in wood or metal, is desirable, as is also experimental mechanics. At first sight, perhaps, too "practical" a course of work; and the educationist may denounce it as utilitarian; but the writer ventures to think such a curriculum may have very great value, both educational and utilitarian.

The English lessons would include history and geography; the geography would natur-

[1] *Continuation Schools in England and Elsewhere.* Manchester University Press, 1907.

[2] Although the present article has reference only to the training of engineers, it may be mentioned that schools of this type are equally suited to students who intend to enter other trades or professions where certain technical training is desirable.

ally have a commercial bent, a form in which it may still have distinct educational as well as practical value. Composition must be taught, and can be well correlated with the other English subjects or with mechanics. Composition is of much greater importance to the young engineer than he is inclined to think; and very great care and trouble is required, especially in the first year or two of such a course, to ensure that students shall learn to express themselves intelligibly.

Mathematics, as taught in the schools, considered, should be of a very practical type, and closely related both to the drawing and the mechanic's work. It may be found possible in the third year to give some knowledge of the elements of the calculus.

The drawing should be connected with both the wood and metal work, as well as with the mathematics; and it will crop up as curve-plotting in other places as well.

No mention has been made in the above curriculum of any language but English; for it must be remembered that the course extends at most over three years, and that the type of student for whom it is intended is often so deficient in English that all available time must be given to the mother tongue. Those engineering employers and works-managers who think of the mechanic as something more than a mere machine

will acknowledge that his average power of description calls for much improvement.

Practical wood and metal work, aiming at hand and eye training, should be begun, but should not take up a large part of the time; later, in the shops, a boy may learn more of turning and fitting in two months than in a year at school. That employers are sometimes glad to get a partly trained apprentice must not weigh with us too much; employers are not mainly concerned with the needs of the individual worker.

Subjects not here mentioned may no doubt be found a place in the course of the pre-apprentice school; the main object must always be to give the best general education possible—education with an engineering bias, but not intended to replace the apprentice-time. Some such school will, we hope, commend itself, both to engineers and teachers, as best for those who leave the primary school at thirteen and at sixteen enter works.

We may now say a word about those in Group I of the table, who, after attending an elementary school, leave at thirteen, or perhaps twelve, and attend a secondary-school course for three or four years. This procedure is much more common than formerly, on account of the rapid growth in the number of secondary schools throughout England; and the very low fees charged have removed one of the great obstacles which

prevented lads of certain social grades from attending such schools. Indeed, with the help of scholarships, municipal or otherwise, and "free places," a boy of average ability from an elementary school should seldom be debarred admittance to a secondary school—of a certain type. When the would-be engineer enters a secondary school, he is placed with his feet on the lower steps of an educational course extending over at least four years—in many cases to eighteen years of age; but should the boy have come from an elementary school at thirteen, he can probably stay only some three years at the secondary school, and he will so profit much less than by following the whole course. He will learn history and geography, mathematics of an elementary type, some French, perhaps Latin, and a second modern language. Chemistry and physics he may have; and "organised games" will take away part of his time. Yet, with all these subjects, each one perhaps so admirable in itself, it must not be forgotten that at sixteen the workshop will claim him; and many of the branches which he has begun to study will be neglected and forgotten. The shorter the time available, the less likely is a secondary-school course to be profitable, and the more we look towards special schools of the pre-apprentice type to solve the problems.

At all events it is good to decide one way or the other. The writer has heard of lads leaving

the elementary school at twelve years of age, attending the secondary school until fourteen, and then taking a course of work at a technical institution until sixteen. The evils of this continual uprooting and replanting are too obvious to need discussion.

We turn now to the training of those who can spare the time for a full secondary-school course, and perhaps go to a university, and who may some day hope to fill responsible positions in the engineering world. No doubt the most authoritative statement recently made in England in regard to this question is the report of Sir William White's Committee to the Institution of Civil Engineers,[1] which should be read by all interested in the question. The Committee is of opinion that the average boy who is destined to be an engineer should leave the public school at seventeen, or eighteen at the latest, and that he should then take one year of workshop practice before proceeding to a university or technical college. The subjects specified for his school course are: Advanced History and Geography, Essay and Précis Writing, Introduction to English Literature, Elementary Latin (but not Greek), French and German—a reading and conversational knowledge; Mathematics—the geometrical side, logarithms, elements of trigonometry, practical

[1] Clowes and Sons, 1906.

arithmetic; Elementary Physics and Chemistry; Drawing. Carpentry or turning, or field-surveying, may be encouraged as a recreation, but should not be required as a school exercise.

As regards the preparatory training, then, of such engineers, the emphasis is very much on general education, as distinct from technical training; and thus the Committee's report will recommend itself to all those educationists who are interested in the laying of a firm foundation. One condition that is yet required to make the suggestions of full effect is that all would-be engineers of this class should look forward to the full subsequent course proposed, one year's workshop practice, three years at a technological school or university, and then two to three years more of workshop practice. As it is at present, there are a number of boys attending first grade secondary schools who are anxious to be qualified to work before the age of twenty-four. The consequence is that the technical-school course is cut down or eliminated, and the public school supplements the special education in the way described by Stephenson[1] in *Public Schools from Within.* There it is said that in the last year of a boy's school life he may be devoting eighteen hours a week to mathematics and science, and coming in contact with a very varied engineering

[1] *Public Schools from Within*, IX, "Engineering," by Rev. F. Stephenson.

plant, including "lathes, drilling, planing, shaping and milling machines, a power hack-saw and tool grinders, and a blacksmith's forge." Such a boy's object is to be able to profit by taking all his workshop practice directly after he leaves school, and so to take some post at about twenty-one.

We may suppose there will always be some who will be forced by reasons of economy so to curtail the course which the Committee regards as ideal. No doubt the tendency will be for more students to lengthen the course on such weighty authority, and in any case everything possible must be done at the public school by making use of leisure time for wood and metal work, and by urging the desirability of some technical course—if short—at a later date, to find room for the literary and general programme put forward by the Committee. When this is made certain, there can be nothing but approval for any opportunity which may come to a boy at school, in workshop or field, to cultivate an *interest*—at a time of life when this sort of interest is very strong—in the metal work or surveying which has the extra charm of being bound up with a future career.

In a paper of the present length it is only possible to indicate briefly how the requirements of the school stage in the education of engineers are being or should be met. The question touches individuals of widely different aims;

and we have shown how long and how far, in different grades of work, the general educational interest may and can survive in competition with the special and professional. In the pre-apprentice school the future foreman or manager is already beginning to feel at thirteen the professional bias in his work, while the future "captain of industry," or consulting specialist, is being told at Oxford[1] that he must not there expect too much professional bias, that a university course must in the main teach principles, and leave the detailed considerations of practice for instructors elsewhere.

[1] Inaugural address by Professor C. F. Jenkin. Cf. *The Times*, October 21, 1908.

XVII

SCIENCE TEACHING AND THE TRAINING OF THE AFFECTIONS

By SIDNEY UNWIN, B.Sc.

IF parents would but do their duty the schoolmaster's task would be an easy one. Unfortunately it is only the exceptional parent who takes the trouble to explain to his child the mystery of birth and the right use of all the different parts of its body. The majority allow their children to grow up in so-called "innocence," and leave them to find out for themselves. And when they have found out, as find out they will, who is there to tell them if they have found the truth? Incredible as it may seem, the average parent bequeaths to his child that most delicate of all instruments—a human body—without any guidance as to its rightful use. What wonder, then, that there is so much self-abuse among our children, so much sin and suffering in our big cities.

If mothers would answer a child's questions naturally and simply, the little one would not be driven to doubtful and tainted sources for its

information. If, instead of ascribing the advent of a baby brother to the doctor, the mother were to tell the child the simple truth, the earliest associations with these wonderful facts would then be bound up with the sweetest of all affection—the love of a child for its mother; and for ever after these subjects would be hallowed by the mother's love. Satisfy the natural curiosity when it arises, however young the child may be, and much danger and often much suffering will be avoided. When a mother finds her child talking about these problems she must not say, "If you will come and ask me any time I will tell you all about it," for the child will probably be too shy to broach the subject. She must herself take the initiative and overcome the natural shyness and reticence all children feel when speaking of these subjects to older people. Not only must every mother unfold to her child the mystery of its birth, but she must prepare it for the changes that are to take place at puberty, and at this point the father must step in and speak to his boy. It is his duty, and he must not shirk it.

But all this is a counsel of perfection. I know from experience that at least fifty per cent of parents never say a word to their children, and therefore the schoolmaster must take the matter in hand. Unfortunately he is at a grave disadvantage, for there is no natural affectionate relationship between him and his boy, as there is

between parent and child; and before he can help the boy in these matters he must win his confidence.

The first thing he must try to banish is all sense of fear. He must be his boy's comrade and friend, and must establish an easy and cordial relationship with him. Some boys will be very shy and suspicious, but this must not daunt him. If he remembers that the only way to win affection is to give affection, and if he concerns himself with the giving alone, the time will come when the boy will respond, and he will then be able to be of real service to him. I place this personal relationship first, for without it no curriculum, lecture, or talks can have their full value. The more the school can resemble the home the easier will be the schoolmaster's task; and the more he can become the foster-parent the greater will be the service he can render his boys.

How, then, shall we organise our school so that we may best be able to unfold to our boys the mysteries of birth and growth, and guide them in the right use of their affections—in other words, how can we best train them to live and to love? We will consider first the environment, secondly the curriculum, including the compulsory and voluntary activities, and thirdly the social life of the school.

Firstly, the school should be situated amidst

beautiful scenery, surrounded by its own estate. This school-state should include a farmyard, a garden, orchard, playing-fields, and river or lake. On the farm there should be cows, pigs, poultry, and bees; and the boys should be allowed not only free access to them at all seasons, but to wander freely in every part of the estate. As the months pass by they will be able to observe the fertilisation of the blossoms by the wind or by bees, the mating of birds, the development of seeds and eggs, the ripening of fruits and bursting of seedpods, the hatching of chicks and tiny birds, the birth of little animals, and the love of parents for their young. Without the right environment our work will not be easy, for

> One impulse from a vernal wood
>   May teach us more of man,
> Of moral evil and of good
>   Than all the sages can.
>
> Enough of Science and of Art:
>   Close up those barren leaves;
> Come forth, and bring with you a heart
>   That watches and receives.

In this last verse we catch a glimpse of the real purpose of our science teaching—it is to develop "a heart that watches and receives"; for unless we can succeed in this, we had better follow Wordsworth's advice and have nothing to do with it. And this brings us to the question of

the curriculum, which I propose to divide under three headings :—

(1) The science work, including nature-study, hygiene, and economics.
(2) The compulsory practical work, including poultry and bee-keeping, farm and garden occupations.
(3) The voluntary work in free time.

The science work should gradually teach a boy to observe and think for himself. He should be encouraged to experiment, to describe his experiments and the conclusions he draws from them. By this means he will gradually become familiar with the facts of nutrition and reproduction, and the laws of growth. He will learn what gives and what prevents health, and how over-indulgence is bound, sooner or later, to produce illness. He must be taught to study living, not "dead," nature, and his attention must be directed not only to the wealth of life around him but to the web of life—to the intimate way in which plants and animals are dependent upon one another, and how they are adapted, or adapt themselves, to their environment. He will soon begin to realise the meaning of "the struggle for life," and will become interested in the way plants and animals shift for their living. Further observation will show him the value of sociability, and his attention must be drawn to the

domestic life of the higher animals and the self-sacrifice of parents for their young.

The study of the animal world must lead up to the study of man. He should be taught why laws are made, and his attention should be called to the written and unwritten laws of the school. This should lead on to an investigation of the economics of the neighbouring village or town, and to further discussion of the relationship between work and wages, labour and capital, the effect of competition and the value of co-operation. He will thus gradually learn to understand the laws which govern his own body, his relationship to nature and his fellow-men, and will discover how to control nature and himself, and get the best out of his fellows.

The compulsory practical work will show him the value of steady and patient toil. In the preparation and cultivation of the ground, the interminable weeding, the sowing of the seed, and the eventual harvest, he will see the result of faithful work. Let him neglect his chicks or his calves for a day or two, and death will teach him something that punishment, artificially inflicted, never may. The care of poultry and bees and the rearing of the young afford opportunity for those boys who want to keep pets. It also brings them into contact with the fertile and unfertile egg, thus enabling the teacher to speak of fertilisation quite naturally. The devotion of

the mother to her little ones, their instant obedience to her call when danger threatens, her gratuitous self-sacrifice for them, show the boy that law is necessary and that self-interest is not the only motive of action. The study of the hive and its inmates teaches him similar lessons.

But while compulsory work has its value and gradually helps a boy to form good habits, we must not neglect to teach him to use his free time well, and to do so I would recommend the giving of prizes for any good work that comes up to a certain standard. Encourage the boy to take up some hobby, such as natural history, gardening, sketching, archæology or architecture. These hobbies prevent loafing—a practice which often leads boys into vice. In the winter, when outdoor hobbies are impossible, boys may be taught some craft, such as leather-work or modelling; or they may be encouraged, especially the new-comers and timid ones, to box, fence, and wrestle, when they will learn the value of keeping their tempers.

Such a curriculum as the one sketched out will help us very materially to train our boys as we wish. But though the environment and the curriculum are important they will not help us unless the social life is good. To ensure this we must have many private talks with our boys in order to tell them individually what we cannot collectively. Assuming that they enter the school

between the ages of eleven and twelve, it is well to see each one during his first or second term to ascertain whether his parents have told him, and if not, to explain to him quite simply the facts of birth. The spring term is one of the best times to treat this matter, because nature is awakening from her winter sleep and giving birth to new life. We can therefore lead up to the subject quite easily.

Before speaking to any boy we must ascertain as much as we can of his past history, in order that we may have some clue as to whether he is likely to have already gained knowledge on these subjects from tainted sources. If the boy's behaviour and character are good it is best not to suggest to his mind that bad habits can be formed; but to answer his questions, tell him the right use of his body, and encourage him to come to you if he meets with anything he does not understand. If, on the other hand, you are almost sure he has got into bad habits, or has gained his knowledge from bad sources, it is best to talk to him frankly about the matter, and make him feel that at all costs he must give up the habit before it becomes too deeply rooted. At the same time he must be protected, as far as possible, from bad influences; and have his hands and mind kept well occupied, so that he goes to bed tired out after a full day's work.

Before a boy reaches puberty it is well to have

another talk with him, and by reminding him of some of the phenomena in nature with which he is now familiar, e.g. the waste of pollen grain in fir-trees, prepare him for the changes that will soon come in his own life.

If you know or suspect that the boy has fallen into bad habits, but is not injuring others, you must beware of frightening him, and making him think that he is wicked. The mental effect of worrying and brooding over his failures is far more serious than any physical effect. He must be taught that in this matter he must strive to gain absolute self-control, just as he has to learn to control his temper and his other bodily appetites. Above all, cleanliness and hard physical exercise must be insisted on, and the boy must be given opportunity to be unselfish. This will be the best cure for his difficulties. Teach him to be a friend to some one, and soon his selfish desires will cease to worry him. At the same time he should be told a little about the analogous changes that take place in girls, in order to prevent him from ever being unkind to them through ignorance; and to a boy who has been taught to observe nature, this knowledge will not come as a shock.

At this point I should like to say a word about the education of girls, for mothers are often content to tell their daughters just the bare minimum, and leave them in ignorance of the facts of sex,

with the result that the young girls either satisfy their curiosity by reading unpleasant novels, or grow up "innocent," exposed to all the dangers connected with this subject. Though the average girl probably does not have such a battle with herself as the average boy, and is innately less uncontrolled, it is no excuse for leaving her ignorant. She ought to know all about herself, and something about the other sex, not only for her own sake, but for the sake of those to whom she can be of help; and this, I take it, is the main sanction for bringing up boys and girls together.

"The fundamental issue in co-education is a moral question," says Rektor Brunn, the head-master of a mixed school in Denmark, where co-education has always been the rule in the villages, and is now the rule in the provincial towns. "It either entails disadvantages and dangers, or has a mutually good influence on both sexes." After a discussion on the subject, which may be found in Miss Henni H. Forschhammer's article on "Moral Instruction and Training in Denmark,"[1] he concludes by saying that in his experience "co-education, when carried on with interest and care, raises the standard of morality."

My own experience is the same. I have found

[1] *Moral Instruction and Training in Schools*, Vol. II. Longmans and Co.

during seven years of observation that the presence of girls makes the tone higher and the life sweeter, that the innate purity of girls makes the dangers of immorality less than it is when boys are thrown only with boys. "Hands off" is the girl's instinctive feeling, while the small boy will often give way to the older one. The companionship of girls gradually helps the boy to gain complete mastery of himself, and convinces him that men must have the same moral standard as women.

Miss Forschhammer's article also gives an account of the attempts that are being made in Denmark to teach systematically the problems of sex as a class subject, beginning with lessons on the natural history of plants and animals, and gradually leading up to the discussion of sexual hygiene and ethics. The results of such teaching seem to have been excellent. In these matters Denmark has done more than we have in England, for I am not aware that any such class teaching is given in this country.

And next, although the title of my article does not allow me, I must ask leave to make a digression, to show how opportunities for unselfishness and service may be given. Perhaps the most powerful influence in a school is the general tone, and a good tone can only be produced by enlisting the co-operation of the older boys and girls in the school government. Responsibility will

often do for them what any amount of teaching will fail to accomplish. As soon as they show any signs of being ready for it some small responsibility should be given them; and with increased responsibility we must provide opportunities for public service. Above all, we must be very patient and allow plenty of freedom for experience. A too rigid discipline and code of rules may very easily crush out individuality and check moral growth, or actually produce vice. We must allow an outlet for the affections if we are to train them. Experience is our best school; and teachers must not only afford ample opportunity for all—especially the older ones—to learn by blundering, but they should tell them frankly their own experience.

Before boys and girls leave school they should be spoken to about fatherhood and motherhood, and should be told of some of the dangers and temptations they will meet in the great world, so that being forewarned they may be forearmed.

Lastly, in the chapel services, which should be as bright as possible, all the teaching must be brought to a focus, and the highest ideals of life must be put before them. They should be taught that religion gives the sanction for these ideals and the incentive to act up to them; teaching as it does that the whole duty of man consists in love to God and love to his neighbour.

XVIII

SCIENCE TEACHING AND A CHILD'S PHILOSOPHY

By CORA B. SANDERS

TO trace the course of the controversy between scientific thought and religion would lead to interesting reflections on the self-consciousness of a generation ; and though such a subject is not within the scope of this paper, a few words may be allowed for introduction. None will contest that the measure of agreement between the two sides has increased during the last half-century. Theology has accepted new knowledge such as it at first seemed disinclined to do ; and science has taken up a more self-critical attitude, defining the scope of natural law, and leaving room, by implication, for a First Cause—knowable, if at all, through some other range of ideas. To many—among them the present writer—the conflict seems to have been much smaller than those on its brink perceived, and to be now philosophically ended.

Whether so much be accepted or not, it will

be agreed that much misunderstanding and distress would have been avoided if each party could have approached the other with a more open mind ; and it is with the object of reducing the dangers of want of sympathy and perspective in such matters that the present paper has been written.

There seem to be two science-religion problems : one personal and philosophical, the other social and practical. In the former case the individual is hampered by some want of fit between the method and fact of science and the needs of faith. This is the side which in writing this paper has been chiefly in mind. In the second connection we meet in practice two types of mind, suggesting different scales of value and opposite courses of action. For instance, it is sometimes hard to see how the full claims of Christianity can be met in a society which is pledged to national competition in an acute form. It is too large a question for consideration now ; but whatever may be said here as to the need for harmonising science teaching with that of religion must ultimately tend, it may be hoped, towards reconciliation in the world at large, as well as in the minds of individuals.

It should be mentioned, in passing, that where in the sequel the words "theology" and "religion" are used, the writer is thinking in terms of the Christian religion as met with in England

at the present day. The harmony to be attained between scientific thought and faith would be found in somewhat the same way in other cases; and much of what is said has no specific implication; but it cannot be forgotten that what schoolmasters and school-mistresses have to deal with in practice is some form—unsectarian maybe—of the Christian religion.

The real degree of agreement, then, is more widely recognised now than it was a few years ago; nevertheless, for a considerable number of individuals the old difficulties still exist (on the Continent this seems to be more frequently the case than with us). Nor is it a matter for surprise, as the attitude of destructive criticism is taken up much more easily than the habit of constructive thought is acquired. A man who adopts the former attitude may take for granted the non-existence of a unity, for the perception of which he lacks the mental equipment.

In our own country, however, the difficulty, I believe, often springs from two much more insignificant sources.

The first is from bad science or poor theology. When either of these great bodies of knowledge is in any of its parts misrepresented, the unfortunate learner is left a prey to mental confusion. There is a good analogy, applying a physical example to mental processes, in thinking of the enormous distortion produced in an image

by ever so minute a flaw in one of many glasses through which a beam of light is sent. When in science teaching hypotheses are treated as fact, or from one established point a whole generalisation is made, such a flaw is created; and it is superfluous to enlarge on the dual criminality of at once disfiguring actuality and violating the true scientific attitude of expectant, patient open-mindedness. Though this happens not infrequently in adult popular science teaching, it probably does not occur in schools, which are now chiefly under consideration. There theology more often suffers.

"Poor theology" should here be interpreted less as bad than insufficient teaching. Religious or theological teaching has been very often in the past given as if simply with the object of keeping alive the religious feelings awakened at home, and any real enlargement of view or increase of knowledge has been left to private exertion. This may have arisen in many cases from hesitation at showing to children the difficulties which such knowledge tries to meet. These points were brought forward at the recent Congress on Moral Education, and are too self-evident to be mentioned without apology.

The other cause of difficulty to which I would point is less generally acknowledged, though it is probably a very common one. It forms the chief excuse for adding a paper to these much-

laboured questions. The sequence in which these branches of knowledge are presented is alone responsible for much misconception. Usually religious knowledge has no beginning in the sense that it is part and parcel of an individual's life; he grows up with it. Science, in the extended sense, is only introduced later, at the very end of school life or even beyond it. Then it may come with a certain shock, as a whole mass of new facts and new hypotheses which cannot be fitted to those already possessed. All the phenomena which by the child were either taken for granted or accounted for by some pictorial tradition are seen as a self-consistent mechanism, and over and over again this new set of ideas takes up the whole mental foreground, either shutting out or overthrowing the earlier series.

The fact that in most schools some form of science is taught from the lower forms upward does not seriously affect this contention; for biology rarely appears save under one of two forms. It may occur as nature-study of a rather stereotyped character, where any trace of a theory of natural order is ruled out of natural history; or secondly, as botany taught on one of the several examination syllabuses which again leave no room for the more general natural theories. All such considerations seem to be rigorously avoided; by some for fear of raising difficulties in children's minds—

the reason cited above as also frequently deterring educators from systematic theological teaching. Others, again, withhold generalisations from middle-school work in conformity with the recent view that the child must itself develop what it learns, and must therefore do without far-reaching hypotheses till the time when the adult mind may be supposed to conceive of them. It is not within the scope of this paper to examine in detail the considerations which, to my mind, diminish the force of these objections, and the more important ones can be gathered from subsequent arguments more easily than at this point.

There is still, it seems then, a science-and-religion problem lurking in a region untouched by the work of the more serious constructive philosophers, a region which may remain for a long time uninfluenced by it. It is usual in every grave difficulty to look to schools for help, and I believe that this one could be forestalled by a slight widening and readjustment of the curriculum and without endangering any other purposes of school education.

Before treating more at length the advantages and difficulties of the suggested change, it is necessary for the sake of completeness to mention briefly some general ideas underlying the whole subject. Without attempting any serious discussion it may be possible to outline a reasonable position in that region where belief or disbelief

must largely influence the educator's method if not his aim.

The average man does not, or cannot, do without "philosophy." However little he may acknowledge it, however crude his conception may be, some picture of "reality" is there. At some time or other every one, almost every one, renders some account to himself for existence, although it may be confused or even shrouded in a general negation.

Using the term philosophy in this very wide sense for the crude individual ideas of metaphysic, it certainly has its place in childhood no less than in later years. Ordinarily intelligent children very soon think about "beginning" and "ending," both for themselves and other mortals. They realise that they are "here" with a natural accompanying sense of curiosity as to the "not here," which further prompts them to the questioning "wherefore?" This is borne out by their comfortable assimilation of teaching as to the "purpose" of this life.[1] This does not need to be

[1] Cf. *Report* of Congress on Moral Education. The efforts made among non-religious moral teachers to supply this feeling of "reason" and "purpose" in existence are usually, by some form of sociological theory, to show the slow evolution of the race, assigning to each generation its particular charge, inherited and potential, in the cause of progress. It is a question whether this fine conception, which appears to fill sufficiently the mental horizon of some adults, can satisfy a child's spirit and lull its first quick craving for a reason, cause, purpose, which is as much a spiritual as an intellectual demand.

further insisted on. To those who have had varied experience of little children, it is abundantly clear that the feeling of "will" is very strong in healthy infants, before the time when they can question its freedom! They only want to know the use of this all-engrossing possession. The early teaching of religion stimulates and feeds these mental and spiritual capacities alike. It shows children by means of simple pictures a world-order in which their immortal personalities have a place and meaning under laws working to one great end; ideas which are capable of expansion with the normal and healthy growth of the mind. It is not overstating the case to say that a great number of educators seriously doubt whether a complete and happy development is possible without some religious training. Indirect evidence, of course, is to be drawn from that widespread fear of disturbing a child's faith and from the willingness so often shown by parents professing no religion to give it a place in the education of the young.[1] At least as far as England is concerned, it may be taken for granted that these facts are appreciated and that an early religious training is the rule. All but

[1] One would like to bring to the notice of those who are not convinced of the necessity of some spiritual food to a child's life the extent to which religious teaching is efficacious (in producing that active satisfaction which we term happiness) amongst those in whom intellectual development is much retarded or insufficient. Teaching of the feeble-minded provides matter for study.

the least active minds, however, are soon ready for a more detailed cosmogony, without danger of its leading to over-speculation.

It would be, I think, pressing the point too far to suggest that science teaching should be co-extensive with religious training, but it would, I believe, be most valuable to give it a place in the regular child-half of school life where it is not practicable to extend it over all school years, remembering how much it adds to the completeness of an individual's philosophy and to the stability of his religion to become acquainted early with current biological knowledge, and realising that while formerly it might have been urged that such knowledge was unnecessary, now the fact has to be faced that it is inevitable.

It will be clearer to consider separately the two sides of science, as in both method and effect the tendencies of organic and inorganic study are very diverse. From our present point of view the organic side presents the most obvious problem.

It is evident from the opening paragraphs that by the teaching of biology here advocated for young children, the mere teaching of any series of organic facts is not meant. The term is to include something more and something different. The theory of organic evolution should form part of the child's stock-in-trade of ideas. In outline it can be grasped by very small children, and I

believe few teachers would find it difficult to interweave it with whatever form the "science" is required to take. In nature-study (as it might be taught for the upper part of kindergarten or the lowest school forms) it makes a thread on which all observations may be strung. Later, where some set botanical syllabus has to be followed, it would call for the sacrifice of only two or three explanatory lessons, after which it would of course form a background to all parts of the work, of such intellectual satisfaction to the small students that the number "interested in science" would be more than doubled. And it might result in the desirable end of the acceptance of some part of animal biology in many curricula where that is now regarded with suspicion. When once the theory has been put forward it need not take a prominent place to the exclusion of observation. Occasional hints are enough to keep it in view, while observations are sorted as bearing upon it or not. The endeavour need not be relinquished even where systematic biological work is impossible; few schools are without occasional isolated lectures, and natural history will no longer be a topic attractive only to the minority known as "bug-hunters" when the small data cited are incorporated with a conception highly interesting to every intelligent person.

Here reference may again be made to the advantage of a simultaneous presentation of the

two sets of ideas, religious and scientific; and insignificant as this point may seem, I think that the importance of its results cannot easily be exaggerated. Once it has been taken for granted that there is no intrinsic problem in science and religion, then all that appears as such resolves itself into restricted knowledge, or simply confusion. Where the two are not learned side by side the last to be understood comes with a different kind of force, due not to its own intrinsic value, but to the increased faculty of comprehension and insight with which it is received. But when both are presented at the same age, growth and development in due course affect both regions equally.

In any analysis of cases in which science is felt to be irreconcilable with faith, one factor, frequently the chief one, resolves itself into a confused conception of Causation. But where knowledge and progress in both fields proceed together, natural law less easily fills the whole view and will assume more naturally the secondary place. To those who have once thought of it as a method (even a "mechanism") there will be little difficulty in accepting another cause; indeed, they will demand it. Some very speculative young people might need a little help here, but more often the co-expansion of ideas will obviate the difficulty.

I should like to note, in passing, the great

assistance which biology teaching of this type gives in the upper half of school to the Divinity lessons, and to the humane subjects generally (though this is, perhaps, beside the mark). Of course, this is chiefly from the point of view of evolution. It is not an easy conception to introduce either as regards ideas or morals. In dealing with the concrete forms of language it would be more possible if a child's knowledge could be wide enough to trace forms through their changes. But any study of organisms not only furnishes many signs of it, but is even unintelligible in the truest sense without it. And having the idea once fixed from the concrete, it may later be applied in other regions with real understanding. In such work we are doing something in the direction of training in constructive thought, though it is, of course, a very humble beginning. However, it is worth while to set men's minds to work on the right track, in the only time when we are sure of the opportunity. Is it not for want of some such preparation as this that teachers are so rarely able to deal with such subjects as the development of man's idea of God, or immortality, in the Old Testament, though they are the very questions on which the fifteen-year-old boy is eager for enlightenment?

In yet another department, a biological point of view might often be a help to thinkers—that is,

the question of the mysteries of life, though these things usually belong to later reflection. Compare the sort of mental worry which attacks some people of imagining an exact point of departure for "spirit," with the scientist's attitude. He has again and again to acknowledge himself beaten in his efforts after an insight into minute beginnings or workings; he does not, however, allow himself to deny any phenomenon because he cannot explain or trace its origin. He knows that a process is no less real because his eyes are too weak, his weights too gross, and his calculations too mechanical to enable him to understand its initial stages. At whatever phase he perceives it, there he faces and acknowledges it, and readjusts his previous conclusions to admit this new element.

One consideration, of importance equally for inorganic and organic work, is that of the place which "laws of nature" hold in philosophy. For lack of training in logic, this is often only perceived confusedly, and we are misled to think of these as something "absolute." Would it be vain to advocate a more general instruction in elementary philosophy? It is at least easy to point out how often a decade modifies current theories, and to put them in their right perspective by showing the alterations, more or less radical, which they undergo from time to time. Thus they can be recognised as what they

are—namely, the formula by which we try to represent to our minds the series of observed phenomena. "Order" being for us a necessity to clear thought, we postulate it for the universe.

I believe that chemistry and physics are generally felt not to have such a disturbing influence on religious ideas as biology. Certainly their effect as a mental training is very different, apart from the general schooling in observation and accuracy which both give. The distinction is, of course, between experiment and deduction on the one hand, and observation and reconstruction on the other. One particular danger from inorganic work to the undisturbed possession of a religious creed lies in the gigantic proportions which "matter" is apt to assume. It can dominate every other aspect of reality until anything which cannot be weighed and subjected to laboratory tests appears unreal.

What has already been said about the simultaneous presentation of ideas would naturally apply in some degree here. Moreover, the general knowledge of biology which has been advocated would help to prevent this one-sidedness. But it is not a danger likely to assail children, only those growing out of childhood and working in the upper forms, where specialising may cause many hours to be spent on one subject. Here, as has just been suggested, it might be worth while to forestall future difficulties

by a little help in philosophical thinking. Whether it came under the head of science or theology, an elementary course in "Theory of Knowledge" or "Metaphysics" would be sure to create interest, and might give just the guidance necessary to prevent the confusion referred to above between apparent and ultimate causation. It seems possible too that a little speculative theory might be introduced into inorganic lessons as well as organic. Laplace's theory, or some suitable astronomical application of "laws of matter," would be useful in bringing these into their right proportion in children's minds—in helping towards the conception that these forces which stagger us by their inevitableness are servants of our universe, not that it is a haphazard product of them.

It seems a work of supererogation to plead now in any particular direction for that co-ordination of knowledge which is being so carefully worked out in many branches. But there is an inclination on the science side especially to dispense too readily with the direct teaching which this would involve. And in practice the results may be likened to turning over a large correspondence without any system of filing and arranging, to be carried on by an untrained worker to whom it is all strange. One who has a firm belief in order everywhere will hunt for some system and learn it; and the genius will certainly invent one; but most will as surely be

overwhelmed and never recover from a state of confusion. Are we justified in not giving at least the key to the best system we have?

Perhaps it is well to turn again to the difficulties themselves, which have hitherto been looked at from the point of view of their origin, rather than as they appear to the person perplexed. For him there is always a concrete problem, some contradiction between a fact and an article of faith, which seems so essential a part of the religious structure that the whole must fall if that cannot stand. This is not the place to deal with any such problems in particular. It is evident that all have their root in a weakening of the hold of spirit. Holding to what is spiritual as the alpha and omega of what is natural leaves little room for contradiction. Futile efforts at a quasi-material explanation of spiritual facts never need confuse the soul. This faith we may, I believe, most easily protect from disturbance by giving early the best we can of science (not limited to one side) and the fullest instruction in religion in our power, taking care, above all, that our training includes specific exercise for that part of "the whole man" to which by careful guiding of the intellect we strive to give full play—I mean worship.

XIX

THE PRESENT CONDITION OF PHYSICS TEACHING IN THE UNITED STATES

By C. R. MANN, Ph.D.

TWENTY-EIGHT years ago there began in America a reorganisation of the methods of teaching science. Prior to 1881, school and even college laboratories were almost unknown. At that time educational theory had reached the stage of recognising that first-hand knowledge was essential to instruction in science. Hence the general lecture demonstration courses, which up to that time had been regarded as adequate courses in science, and which were supposed to give the students some comprehension of the broad underlying principles of science, began to be discounted. There arose an insistent demand for laboratories and for individual laboratory work on the part of the students, and educators and science teachers were united in the belief that could laboratories be acquired the problems of teaching science would be solved.

In response to this earnest demand, laboratories

have been forthcoming, until to-day there is scarcely a secondary school or college in the country that does not offer laboratory work of some sort in some of the sciences. Thus the past thirty years has witnessed a tremendous advance in the methods and facilities of science teaching, an advance which has had important effects on other subjects as well, since we now hear of studying history, economics, and even Latin by the laboratory method.

Yet in spite of the universal recognition of the great progress that has been made, most educational authorities and many science teachers themselves are now raising the question whether, in the light of past experiences in education, we in the United States are now making the best possible use of the laboratory facilities thus acquired—whether the educational results now being obtained justify the time and the money expended on the laboratory work. We are beginning to see that the acquisition of laboratories has not by any means solved the problems of science teaching, but that the experiences of the past fifteen years have shown that we do not yet know how to use laboratories most effectively, and have served in defining for us some of the other and larger problems that must now be solved before science shall be able to make further progress in elementary education. If we would understand the present conditions, we must glance for a minute

at several of the larger factors that have been prominent in their development.

Perhaps the most powerful influence in shaping the courses of study, including the laboratory work, in the secondary schools has been that of the colleges and universities. These institutions have in the past controlled the kind of work that was done in the secondary schools through their entrance requirements and their preparation of teachers for those schools; and this influence has been inspiring and of the greatest value in establishing standards for the secondary schools during their period of adolescence. Therefore the development of science in the colleges has been reflected in the lower schools, so we must look to the former for light on the peculiar development of the latter.

During the period under consideration there has grown up in the colleges and universities a profound reverence for the idol of research; and this in itself worthy reverence has been generally fostered and encouraged by university authorities, by making it clear to the teaching staff that academic promotion would in large measure depend on ability to turn out work that might be classified as research. Those who were preparing in colleges for teaching science in the secondary schools very naturally became infected with this research idea; so it was not strange that the phraseology and manipulations of research

made their way into the elementary instruction in science. College courses were designed to give training in the technique of science in preparation for research, and secondary-school courses were modelled after the college courses. Thus the idea of educating young people through science has been for the time being lost sight of; and, carried away by an enthusiastic and eminently worthy spirit of research, science teachers, as one of their number has aptly put it, have been so busy trying to teach science that they have forgotten to teach boys and girls.

Had this enthusiasm over research resulted in the infusion, along with the phraseology, of the spirit of research into the elementary work, yet greater benefits than those actually apparent might have been obtained. What was actually done, however, was to transplant the forms and technique of the research laboratory into the high-school laboratory, with the expectation that children of high-school age would appreciate them. In other words, until very recently no effort has been made to develop the scientific habit of mind in connection with materials with which the children are familiar, in which they are already interested, and concerning which they have some native curiosity.

In the modern physics course, for example, the pupil is at once set to work measuring with micrometer calipers, finding specific gravity by

seven different methods, determining various physical constants, moduli, coefficients, and specific this, that, and the other; all by carefully expurgated classical methods, and all in terms of a highly specialised, refined, and to him unusual set of units. The work is not in itself bad, but is beyond the range of vision of most high-school pupils—they are getting too much of a good thing. The result has been to carry the work farther and farther away from the vital interests of the live boy and girl, and to convert many school laboratories into what the Germans call "*Sterilizirungs-anstalten.*" That very similar conditions have prevailed abroad must be evident to careful students of the reform movements in France and Germany.

Another distinctively American influence that must be considered, if we would understand present conditions, is the universal practice of measuring the work of the secondary schools in terms of "units." A unit course is one in which the subject is studied five times a week for one school year. Because the curriculum contains many electives, it has been found impossible to arrange a course that meets twice a week for one year and three times a week the next, as is done with such good effect abroad. Hence, whatever physics, for example, a student gets must be given him in one year. There is no chance for the gradual preparation of his mind for the more

difficult concepts, and no repetition the following years by which to clinch them.

It is, of course, a well-recognised fact that no very fundamental knowledge of any subject can be acquired in this limited amount of time; especially when the pupil is trying to master at the same time four different subjects, and when each of these subjects has been expanded to such an extent by the recent advances of knowledge. The number of new and often difficult concepts that a student is called upon to apprehend clearly each day is far too great. No child ought to be expected to grasp them all, and to keep them all distinct yet in ordered sequence in his mind. That children do not, as a matter of fact, gain clear comprehensions of the concepts presented in science, and that they are, therefore, unable to think clearly, thus missing one of the greatest possible advantages of science study, is evident on every examination paper.

A particularly good opportunity for observing this failure on the part of science teaching was recently given at the University of Chicago. The university offered a prize scholarship in physics, open to competition to the students of all its affiliated schools. The schools naturally allowed only their best product to compete. Yet there were but two of the twenty-two papers handed in that did not contain several statements like the following, which are taken from these

prize papers: "Work is the force exerted to impart motion to matter." "I know that red light has the longer wave-length because they always do. It is a known fact." "The force that it will take to raise a hundred pound wagon up a 5 ft. in 100 ft. inclined plane is 2000 lbs." (which he proceeds to prove). "The work done equals the amount of power that can be exerted directly against the resistance that has to be overcome." "By Archimedes' principle a body displaces its own weight in water." "The efficiency of a machine is the amount of power received divided by the amount of force exerted upon it." "The wave-length of red light is longer because in the aurora red light stands out more than green."

Examples of this sort show clearly that the pupils have not obtained from their scientific study clear and definite concepts of the things studied, so that clear thinking, which science, if anything, should develop, is impossible. If quantitative work means the acquirement of definite and clearly definable concepts, which is the generally accepted idea of it, then the present type of quantitative work, in which so great emphasis is placed on measurement for its own sake, fails to attain the result sought. As stated above, the so-called exact measurements are but the forms and technique of research without its inner spirit, and so the teaching often degenerates into a mechanical operation.

A careful study of the science teaching of the present time in America reveals a number of causes for its partial failure to inspire youth and to implant definite concepts. Some of the more important suggestions as to what these causes may be are the following, each of which suggests a line of educational investigation which must be followed up experimentally before science teaching will attain its greatest efficiency :—

1. The concepts taught may be intrinsically too difficult to be adequately grasped by children of school age. 2. The concepts may be too numerous for the time available, and so may follow one another in too rapid succession to allow of their being clearly grasped as they flit by. 3. The concepts have no appreciable significance for the pupils, in that they are too remotely connected with or derived from their daily lives, and too little applicable in the solution of their immediate problems. 4. Passing an examination may be the purpose of the study, leading to an attempt to memorize words rather than to grasp ideas. 5. The concepts are not understood by the teacher or clearly presented in the text, because of the muddy condition of present metaphysics and the lack of any clear and comprehensive knowledge of the processes of scientific reason-

ing. 6. The seeds of the concepts are not sown early in the school life, and their growth is not fostered by repetition and use of them over a period of years; so that they have no concrete foundation in the personal experiences of the child, but are first presented to him abruptly either as definitions or laws, or through a single experience with some, to him, bizarre piece of apparatus.

The limits placed on this article will not permit of an extended investigation of these various suggestions. In closing, in order to dispel any impression that this is a too gloomy or pessimistic view of the present situation, I will forecast the future by stating some of the problems that have been defined by the experiences of the past twenty years, and mentioning the lines of work that have recently been opened up in America looking toward the solution of these problems. When we recall that the clear definition of a scientific problem is half the battle, we recognise how great a contribution to the future efficiency of science teaching has already been made.

There have been formed in the past three or four years in America a dozen or more national educational organisations, each dedicated to a scientific study of some one of the more important of the present problems. The specific

problems attacked, and the organisations that have attacked them, are, for science, the following:—

1. How can nature study be organised in the earlier grades so as to preserve the investigating spirit of childhood and yet to lay in the individual child through his own concrete experiences a firm foundation for later scientific and technical work? The American Nature Study Society has just taken up work on this problem.

2. How may the study of the industries and industrial work be organised and treated in the later grades so as to foster the scientific habit of mind and to store up in the individual those concrete experiences that are essential to his own immediate growth and to laying a firm foundation for his later study of science, pure and applied? This is one of the problems now before the Society for the Promotion of Industrial Education.

3. How may the work in the secondary schools be reorganised so as to foster the habit of solving problems scientifically, to use effectively the materials gathered in the earlier work, and to train in habits of clear scientific thinking? This problem is that of the American Federation of Teachers of the Mathematical and the Natural Sciences.

4. How may educational standards be defined and enforced so as to foster and not impede

effective growth in educational efficiency? The National Bureau of Education is considering this problem.

5. How may colleges and universities reorganise their instruction in science so that a broad conception of the activities of science may be given to those who do not become scientists? This subject is being agitated, but no organisation has as yet seriously attacked it.

6. What may colleges and universities do to advance the theory and practice of education and to train more effectively the teachers for the lower schools? The Association of College Teachers of Education exists for this problem.

7. Is the true scientist a realist, a materialist, an idealist, a pragmatist, or what? What are the philosophic foundations of modern science? What is the modern logic? While I know of no society in America that is devoted exclusively to the study of these problems for science, the great wealth of current literature on these topics, especially in France and Germany, shows that they are under serious and very active consideration.

The present is thus a time of intense activity in education. For science it is a time of great opportunities. On every side the opinion is expressed that these new problems may be solved only by the scientific method of experiment. So experimental schools—educational laboratories—

are beginning to appear; and the number of able men who are turning to this scientific study of education is rapidly increasing. Popular demand for science of the right sort is on the increase, and its value as an educational agency will increase in proportion as science teachers apply their own methods to their teaching problems. We may therefore look forward to the future with confidence, well knowing that the results of the present tendencies will be that the study of education will become a science, and the study of science an education.

XX

SCHOOL SCIENCE IN GERMANY

By THE EDITOR

THE writer's interest in this subject was first aroused years ago in Giessen, when a schoolmaster of that town produced a copy of the *Zeitschrift für den Physikalischen und Chemischen Unterricht*, and enquired whether we had such journals in England. Confession was made that the equivalent hardly existed, although indeed science teaching was touched upon in this and that weekly or monthly. Then the overwhelming answer: "But we have a journal for every subject."

Returned to England, and teaching again, it seemed virtuous to order the paper specially (almost exclusively) devoted to the teaching of physics; and it cannot be questioned that the *Zeitschrift* provides interesting reading for the reflective teacher, as well as numberless experimental tips for those who are ready to try them. These notes on the growth and present state of science teaching in Germany are largely due to its help; and if this article passes on to others the same

interest in comparisons of a suggestive sort, it will have done its work and will have the *Zeitschrift* to thank.

To lead right up to the present from historical beginnings would take us too far: an account of that side of the question is to be found in a recent paper by J. Norrenberg,[1] among others. From this are taken a few important facts in the later stages of the development.

At the end of the eighteenth century the schools were beginning to feel the effect of the *Aufklärung*, the movement which led to an educational ideal of a more robust and active humanity than that represented in the *litterata pietas* of the earlier Gymnasia, or classical schools;[2] and they were also affected by the systematic work of Linnæus in the realm of natural history. Both influences tended to make a place for teaching in science, and by 1800 definite hours for science work were set apart in many of the Prussian Gymnasia. After the fall of Napoleon there were general reorganisations of the country's forces, including its educational system: and it is worthy of note that in Süvern's Prussian Code, of 1816, the natural sciences were given two hours a week in

[1] *Geschichte des naturwissenschaftlichen Unterrichts in den Löheren Schulen Deutchlands.* Trubner, 1904.

[2] For a fuller account of German educational terms, cf. Paulsen, *German Education*, tr. Lorenz (Fisher Unwin, 1908), preface, pp. xii–xx.

the gymnasia, and a place in the syllabus of the leaving examination. Materials and teachers, however, were not available in full tale, and the vigour with which educational authorities pressed home at this time the importance of education, led to a great deal of overwork in the schools; so that when, after a long trial, the code was reconstructed in 1856, natural history and physics disappeared from the leaving examination of the Gymnasia, and they have never been put back.

By that time, however, another type of school, the *Realschule*—a type developed from a variety of technical school of a grade lower than the Gymnasium—had developed into an institution aiming at a sound general education on lines less classical than those previously in vogue; and the *Realschule* received as such official recognition in 1859. Such schools had a special interest in scientific knowledge, and their coming gave to school science a position and an opening of which it has in many ways availed itself during the last half-century.

Norrenberg gives an interesting account of the programme of a *Realschule* at Meseritz in Prussia in 1851. We find that out of forty-five periods a week in the first class—such was the substantial allowance—two were given to physics, three to chemistry, two to natural history, and three to four hours to "technology," whilst in the second class eight hours in all, in the third class seven

hours were devoted to natural science. It may be supposed that the work done in such a school —democratic in tone as the *Realschulen* were— was very much of the useful, practical, encyclopædic sort, but in high places there was a movement on foot to emphasise the formal, mind-training side of the work and the human element in all knowledge of the material world. The Prussian scheme of 1859 (Wiese's Code), which gave the *Realschulen* their position as institutions giving a general education, contains the following words—much quoted among writers whose main interest is on the humanistic side :—

> "As to the success of *Realschulen*, everything depends on their avoiding the danger which comes of much contact with a wealth of material things and of empirical knowledge, when it is not impressed upon the student that the deeper ground of all reality lies in the mental content and value of things, and that the visible, tangible world rests upon the invisible and spiritual."

The exact sciences began, from this time, a steady upward course; new teachers were required, new demands were made on the universities, new professorships created, and new laboratories built. The rise of a number of science masters who had themselves been able to enter the university from the *Realschule* gave

a new impetus towards the realising of Wiese's humanistic aim; for men who had themselves gained many of their ideas about life and living in the study of the material world were much more likely to convey these ideas to others. Such men saw the need for equal opportunity in all types of school which could reasonably expect to send boys on to the university, and urged the humanistic value of their own subjects.

As an example of the defence of the "humanistic" element in science teaching we quote a paper by Höfler, which appeared in the second volume (1888) of the *Zeitschrift* already mentioned. Waving aside the view that the bearing of science on latter-day life and industry can be defended as ground enough for its inclusion in the school course, the author goes on to say that the aim of the realists is a clear grasp and enlightened valuation of the actual, both in mind and matter. Such realism may oppose itself to formalism and verbalism, but does not clash with any true humanism.

This feature, the humanistic value of science teaching, has been the key-note of much recent work, and so we shall follow Höfler a little further into the details of the special subject of his paper —physics teaching, a matter on which he is an accepted authority.

School physics is to be mind-training, with inductive logic as its peculiar sphere—teaching

complementary to the mathematician's usual training in deductive. It is urged that the work gives facility with quite other subject-matter, and he quotes with satisfaction a former pupil's report, that the methods of his school physics had come usefully to mind when he had had to take sides on a question of political economy. Höfler explains that the best method for extracting this inductive training is to hold as closely as may be to the line of historical advance, getting help from such studies as those of Ernst Mach;[1] and that it becomes the teacher's practical problem to adjust the rival claims of the historic and systematic orders, and to find a middle path. The history of physics is to be not only a means, but an end in itself; and Höfler suggests, as an example of this, a course on the great astronomers (as might be found for English readers in Lodge's *Pioneers of Science*). The source of much ill-success in the past is to be avoided, namely, that science has been presented in ready-made doses, without enough consideration as to the fitness and state of development of the receiving minds; and so nature is first to be introduced as a whole to the heart and mind of the child, before he is led into that artificial way of ordered enquiry which mankind has only achieved after centuries.[1] At its best and highest, physics is to be not only the type of an exact science, but a medium through

[1] Cf. Dr. Mann's views, expressed in the foregoing paper.

which man perceives the beauty of nature and its harmony in relation to himself — "Science so modestly playing a part hand-in-hand with the great literatures of Greece and Germany, whose ideals are the highest the educator has to teach."

Such a declaration of faith would probably be signed by a number of leading German schoolmasters at the present time; it asks in general for humanistic value, and in particular for critical completeness in the higher classes. Indeed, several recent meetings have considered the problem of adding the "Introduction to Philosophy" to the science course, such matters as the relation of the psychology of the sense-organs to the study of physiology, the study of such concepts as matter, force, causality, giving easy chances of dove-tailing.

With these wide aims the need for severe *selection* of material arises: and the tendency is towards uniformity of excision and keeping in line with some standard book, which emphasises important matter by change of type, confines itself on the whole to the simplest material, and treats it in the most complete way, since this is best for the grasping of the formal side.[1]

The latest summary of this work of selection is to be found in the report of the Meran Com-

[1] Höfler's *Physik, mit Zusätzen aus der angewandten Mathematik, aus der Logik und Psychologie* (Vieweg, 1904) does this for physics. Eng. tr. in the press.

mission,[1] where it occurs in conjunction with a statement of the amount of time which those interested in science claim for it. The scheme of hours drawn up by the Commission has been adopted for future *Oberrealschulen* in Bavaria, and these appear as follows:—

HOURS PER WEEK

Class	I	II	III	IV	V	VI	VII	VIII	IX
Geography .	2	2	2	2	2	2	2	1	1
Mathematics .	4	4	4	5	5	5	7	6	6
Physics .	—	—	—	—	3	3	3	4	4
Chemistry and Mineralogy.	—	—	—	—	—	2	3	3	3
Biology and Geology .	2	2	2	2	2	2	2	2	2
Other subjects	17	17	17	17	16	15	13	14	14

This scheme rather more than fulfils, in fact, the requirements of the Commission in regard to the "modern" schools. Something is also said by the Commission as to the teaching of science in the *Gymnasien.* It is urged that a good grounding in natural science is highly necessary also to boys attending schools of this type, at least so long as such schools are in the majority and educate the majority of future directing classes. As a first step, it is contended, the two hours a week devoted to physics should become three, so that "at least in one department natural

[1] Commission appointed by the Association of German Scientists and Physicians, Meran, 1905.

science should exert to the full its educative value." The commissioners confess that they are unable to cope with the problem of teaching other branches of science in the classical schools, except by suggesting the sacrifice of more time now devoted to classics (a point impossible to be gained at present), and so they content themselves with pointing out to the authorities a "yawning gap" in the science work of the *Gymnasien.*

Though the sympathy of the teacher of science will instinctively go out to such as make this claim, it may be questioned whether the modern schoolboy (and especially the German schoolboy) is not already too much pressed by the onrush of an "all-sided" education. Kerschensteiner[1] cries out bitterly that the structure of the new Bavarian *Oberrealschulen* is supported on four pillars—as many pillars as there are sections in the qualifying examinations for secondary teachers—and that if there had been twenty teachers' departments there would have been twenty main columns on which to build the education of the miserable young victims. All education, he says, should have one main support, whether ancient or modern languages, science, technology or art. Such great ranges of intellectual activity demand in their school treatment—one as much as another—emphasis on practical moral notions of perfection, of justice, of goodwill.

[1] *Grundfragen der Schulorganisation.* Trubner, 1907.

Many of these alternative systems are not easy to realise in practice: probably some sort of directly linguistic or historical study will claim an important place in all education for some time to come. But Kerschensteiner's view may well remind us that by crowding in an extra hour for a neglected subject we shall not necessarily improve the whole; and it may be that the position of science in the *Gymnasia* as a non-tested option is as good an arrangement as is practically possible: especially if we might assume that the work on the classical side aims at supplementing in some way the scanty experience of the concrete and inductive, as, for instance, in archæological work.

The main principles laid down by the Commission for the teaching of physics in all sorts of schools are three: That physics should be taught as a natural science, and not as a branch of mathematics (since the mathematics and physics are often taught by one man this contention is not so unnecessary as it may seem); that it should be taught so as to serve as a pattern for methods of winning new knowledge in any experimental science; and that regularly organised practice in observation and experiment at first hand is requisite for all scholars (a greater novelty in Germany than in Great Britain, and more fully discussed in the sequel).

The Commission also makes full recommendations concerning chemistry and biology, and it

will be seen from the scheme of hours given above that in the upper classes time is devoted, in the "modern" schools, to each of these subjects as well as physics. In chemistry the practical element is not yet so strongly represented as in English schools; but here, as well as in physics, this problem is much discussed, and individual teachers are working out their own courses in their own way; rediscovering points of method and management that may be old and familiar to English readers, but always with a broad philosophic interest that gives the impression of building—slowly perhaps—on firm foundations. Biology in the upper classes is only now acquiring the position it claims; in the days of rising Darwinism it was to such a degree suspect among the orthodox in high places that in the code of 1882 it was ruled out. The average time allotted to it at present is not great; and although all will agree that some acquaintance with modern biological theory and practice is of the utmost value in training a boy as a thinking citizen (a point far too little recognised in English schools), it may be impossible to find room for it in every boy's time-table,—except such urgent matters of personal and public hygiene as can brook no hindrance. Let us hope that at least some pupils, whose keenness lies that way, will get a grounding good enough to spread among the rising general public a lively and critical interest in the

attacks of science on the problem of life, of all problems most fascinating and most formidable. Among girls especially, where the mathematico-physical and engineering interests do not elbow their way so ill-manneredly to the fore, it should be possible to reach a high standard of biological attainment; but time must elapse before the higher education of women in Germany reaches dimensions comparable with that of the men.

It has been said that the question "in the air" in Germany at the present time among science teachers is that of practical classes. Noack, in Giessen, was one of the first to start such work, the experiments following the demonstration and discussion in the ordinary classes; later K. T. Fischer, by his enquiries into the methods adopted in England, America, and other countries, and by his numerous publications on the subject, has helped to create a body of public opinion, which, though it does not accept such extreme heuristic views as those of Armstrong, is at least ready to put the practical exercises first, and make them the basis of the whole work. The chief difficulties in the way are the cost of equipment and the training of teachers in the practical work. Fischer[1] sketches out a useful extension of the ordinary course of university lectures in physics, which should give, in four hours a week for three years, a very good grounding in the teaching

[1] *Zeitschrift für den Phys. und Chem. Unterricht*, 1907, p. 16.

aspects of the subject. His extra course includes: lectures on the growth of physical concepts (cf. Mach's writings); exercises in manipulation; students' demonstrations of class experiments; discussions regarding recent researches; and, where possible, a piece of research work (three days a week for one year). Then the student spends at least a year as assistant in a secondary school before he is appointed to an independent post.

There seems no doubt that Germany must tackle this question of training the schoolmaster who is to be experimentalist and pedagogue in one: and when done we may be sure it will be done thoroughly. If such teachers only succeed in escaping a too rigidly uniform and economical organisation, the prospects are very hopeful: given that the schoolboy is not worked hard enough to lose his health and mental "spring." We may confidently expect in the next generation not only men of free and independent judgment with a reverence for natural law, and counting among their number many who will have been inspired to widen the bounds of mental and natural science, but also—a word to the hard-headed—men who will carry the method of exact observation and inference into fresh regions of application and industry: wielding, with renewed skill and renewed zeal, powers they already inherit, powers of unfathomed import in the economic conquest of the world.

XXI

SOME PRACTICAL NOTES ON THE PLANNING OF SCIENCE LABORATORIES

By T. H. RUSSELL, M.A.

MANY are the infallible signs of the widespread extension of science teaching in schools and other educational institutions; and this teaching is not confined merely to the holding of classes and lectures, but as time goes on, more and more practical work, work done actually by the students themselves, is being carried on.

This increase of instruction in science has, of course, necessitated the provision of suitable accommodation, but although an endless number of science-rooms and laboratories have been, and are being, fitted up, the literature bearing on this subject is, by no means, increasing proportionately. This is due to various reasons, such as the changes that the methods of science teaching have undergone, variation in the requirements and conditions in individual instances, the personal views of different teachers or governing bodies, etc. Nevertheless, although it would be unwise, if it

were practicable, to attempt to standardise methods of planning and fitting-up science-rooms and laboratories for teaching definite branches of science, it is considered desirable to include in this series of articles on science in schools a few practical notes on fittings for science teaching.

Firstly, let us consider the building or rooms in which the work is to be carried on. It can be hardly necessary to warn the reader of the dangers of converting existing rooms into laboratories for practical work. How frequently the result is unsatisfactory, if not actually disastrous, can readily be seen by inspecting such conversions in one's own neighbourhood. Doubtless the cause is more often lack of funds rather than mere ignorance. One sees drains and pipes in awkward positions and unsightly profusion, draught-flues much in evidence and equally ineffective, windows and doors unsuitable in size and inconvenient in situation. Then we have the instance of the school that wanted a chapel but built a laboratory, because they could get a grant from their County Council for the latter but not for the former; afterwards converting the laboratory into a chapel. Who knows but that chapels are not sometimes converted into chemical laboratories!

Much good work, if the teaching is sound and on the right lines, can be done amidst simple and inexpensive surroundings; in fact, not infrequently

success is inversely proportional to the amount of polished mahogany and plate-glass and the palatial appearance of the laboratory. On the other hand, apart from the efficiency of the building, the moral and physical effect on the students of a well-arranged, properly ventilated and lighted room cannot be ignored.

Before the erection of a new science-room or laboratory is commenced, the details and arrangement of the fittings, ventilation, lighting, and heating should be fully considered and settled. It is no uncommon thing for the rooms to be built first, and then, when completed, the question of the fittings, etc., to be worked out by somebody else—teacher, architect, or school-furnishing firm—called in only at the last moment.

Nowadays the modern tendency here, as in domestic and other buildings, is simplicity, and the key-note is simplicity in character as well as in arrangement. The fittings should be, as far as possible, of an inexpensive nature, but, unlike much of the present-day household furniture, which is suitable only for these times of continual change and unrest, they must be substantial.

It will probably be advantageous to consider here those science-rooms and laboratories which are intended more especially for work in elementary science, chemistry, and physics. We may note, in passing, that in secondary schools where the mixed system is avoided, that is, where

separate class-rooms, etc., are provided for the boys and girls, it would not be necessary to duplicate "rooms for special instruction in science, art, etc." The number of hours given to these subjects is so small that some arrangement can generally be made for such rooms to be used by the boys and girls in turn.

When school laboratories are being planned it is very desirable that both future enlargement and changes are kept in mind, as these are so often required afterwards owing to increase of students or alterations in the methods and character of the teaching. The fittings must be arranged so as to give the instructor ease of supervision of, and access to, the pupils, and the latter the least possible excuse for constantly moving from one part of the laboratory to another. The work of the laboratory-attendant and the cleaner, who have to keep the room in a clean, neat, and orderly condition, must also be considered and reduced to a minimum.

Within so limited a space it is not proposed to attempt to describe all the fittings for chemical and physical laboratories, but merely to point out some of the general principles to be observed.

Science-rooms for elementary work are usually provided with a simple type of bench for the pupils and a long table for the teacher, with some fixed shelves or short benches against the walls;

cupboards and drawers, a blackboard, and one or more sinks complete the essentials. The benches should be strong and steady, but narrow, that is, not more than twenty-eight or thirty inches wide, with the pupils on one side only, so that they all face the teacher. But the space between the benches, say, at least two feet nine inches, must allow the teacher access to each pupil. Some illustrations of special fittings for science-rooms were given in the writer's *Planning and Fitting-up of Chemical and Physical Laboratories*, published by Batsford in 1903. Small schools are frequently provided with only one room for the whole of the science-teaching, and therefore require special modifications, but the larger ones, where more advanced work is done, have separate rooms for chemistry, physics, botany, biology, etc.

It is usually stated that chemical laboratories should be lofty, but although this may lessen the unpleasantness of the unavoidable fumes and smells, it renders the efficient ventilation and warming somewhat more difficult. The laboratory may be lighted by skylights or windows, or by both; the windows should be kept high, at least five feet above the floor, especially as wall-space is most valuable for shelving, etc. Light from the right or left hand is better than front or back light for work at the benches. The laboratories and lecture-room are very often placed on the top floor in secondary schools; this arrangement has

the advantage of making it easier to obtain a particularly good light for them.

Ventilation that is sufficient for ordinary class-rooms may be insufficient for large chemical laboratories, but the system, whether "natural" or mechanical, that is best to employ depends mainly on questions of magnitude, cost, position, etc. It is frequently urged that the "plenum" system is unsuitable for schools, as its proper working demands the windows being always kept closed, and therefore does not encourage the pupils to open the windows in their own homes. This disadvantage can be partially overcome by working the "plenum" system in the winter only. The reverse system—the "vacuum" or sucking-out—if less reliable and thorough, is much less costly. "Natural" ventilation is gradually becoming better understood; but as it depends solely on the air-movements due to the wind blowing, and to the sun shining on one side of the building only, the results are necessarily extremely variable; and not eminently satisfactory where a large number of human beings are crowded together. In a school laboratory it is often highly desirable to be able in emergency to get a strong through-draught by means of open windows.

The walls should preferably be washable, and light in tint; a high dado of glazed bricks or tiles with distempered plaster above makes a suitable

surface. The floor must admit of being easily and thoroughly cleansed, and the whole length of every pipe, drain, or channel below the floor must be very readily accessible. It is a great advantage to keep down the dust on the floor, and there are now several preparations for this purpose on the market. "Florigene" was tried, and reported upon in the *School World* for April. The test is described as most satisfactory; not only was the dust rolled up in a layer of oil and easily removed during the process of sweeping the floor, but its rise and consequent dissemination was prevented during school-hours. Its use was not considered to entail any additional fire-risk. It was noticed the floor became somewhat darker in colour and that the oil was apt to come off on any clothes brought into contact with the floor, but these effects would probably somewhat pass off after a time; the manufacturers suggest its use three times a year only. It can be applied to wood, concrete, stone or polished floors, or to linoleum. One of these preparations contains an antiseptic. Then there are the "Ronuk Sanitary Polishes," applicable to all kinds of wood floors; the manufacturers claim that the pores of the wood are filled up, so that no germs or dirt are harboured in the floor-surface, that their preparations are largely composed of antiseptic materials but without any disagreeable smell, and that scrubbing is dispensed

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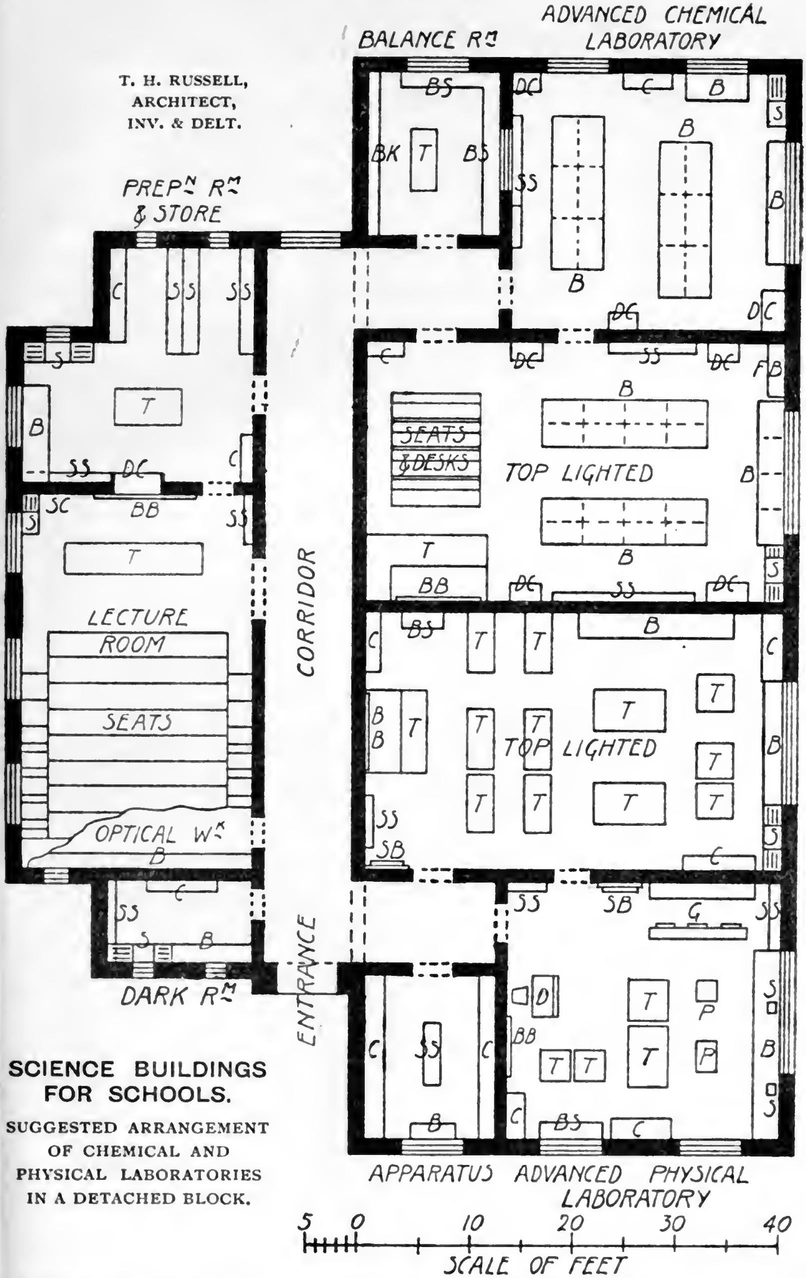

SCIENCE BUILDINGS FOR SCHOOLS.

SUGGESTED ARRANGEMENT OF CHEMICAL AND PHYSICAL LABORATORIES IN A DETACHED BLOCK.

B, Bench.	BB, Blackboard.	BK, Books.	BS, Balance-shelf.	C, Cupboard.
D, Desk.	DC, Draught-closet.	FB, Furnace-bench.	G, Galvanometers.	P, Pier.
S, Sink.	SB, Switch-board.	SC, Screens.	SS, Shelves.	T, Table.

with, only dry rubbing being necessary after the first application.

Now as to the arrangement of the students' benches in the chemical laboratory. As a general rule, they should not be fixed along the walls, chiefly on account of difficulty of proper supervision; draught-closets, shelves for bottles and balances, combustion-benches, cupboards, and blackboards are better against the walls.

Work-benches are single (about two feet six inches wide) or double (four feet six inches to five feet wide); in the latter case half the students face one way and half the other, but these double benches are obviously more economical of floor-space; the gangways should be at least five feet wide, so that the teacher may be able to pass between the two rows of students. Dr. R. W. Stewart has most carefully worked out a set of formulæ for the best dimensions of the room to secure economy of floor-space (see *School World*, January, 1905). There should be a floor-area of thirty to thirty-six square feet per student, including all gangways, etc. Each worker, or pair of workers, if they work in twos, will want from three feet six inches to four feet length of bench. The demonstrator's table is usually somewhat raised above the floor-level, and there should be sufficient space in front for the students to be able to stand round to see an experiment, etc. The bench-tops are thirty-four to thirty-six inches high with cupboards and drawers below

(to contain the apparatus, etc., entrusted to the workers), a separate set, if possible, for each class. There should be a sink, gas and water taps, rubbish-tray, and perhaps electric-current terminals within reach at each bench-place, but the working space should not be hampered with partitions, tiers of shelves, etc., although a small draught-hood or enclosure is convenient. Small strongly made balances may be provided for each student, but the delicate ones are best kept in a separate adjacent room, or at any rate in enclosures fixed against the wall of the laboratory (preferably at a distance from the draught-closets). It is often said the balance-room should not be entered direct out of the chemical laboratory, as the fumes from it are injurious to the balances. On the other hand, youthful students are apt to spend too long there talking and wasting time if it is not under the direct control of the teacher; sometimes a window or glazed screen can be arranged so as to overcome this disadvantage. Also on account of the acid fumes in the laboratory, metal-work should be avoided or reduced in amount as far as possible; this refers especially to drawer-knobs, gas taps, etc., usually seen in a corroded and unsightly condition. Bronzed ironmongery stands better than polished brass.

In laboratories and science-rooms there is a greater fire-risk than in the other rooms in school buildings, hence special precautions should be

maintained to ensure the prevention of fire. Last year the London County Council issued the following revised regulations on this subject :—

REGULATIONS FOR THE PREVENTION OF FIRE IN LABORATORIES AND SCIENCE-ROOMS.

(1) When the laboratory is in use, an adult teacher must always be in charge;

(2) In laboratories which are used only by day scholars, the head master or head mistress must have the custody of the key, which must not be left finally in the possession of the laboratory monitor after the close of the school;

(3) When there are evening classes a second key is provided, which must be in the custody of the responsible teacher;

(4) The person in charge, at the time of leaving, must satisfy himself that all taps are turned off;

(5) Charcoal that has been heated must be placed in galvanised sheet-iron boxes, which must always be closed when not in use, and which should be mounted on asbestos or stone slabs;

(6) No unauthorised person must be permitted to enter the laboratory when it is not in use;

(7) The receiver of the waste from the sinks must be carefully cleaned out at least once a week;

(8) Inflammable liquids (such as waste alcohol, methylated spirits, ether) must not be poured down the sinks;

(9) Very great care must be taken when using sodium, potassium, or phosphorus (or when cleaning out bottles which have contained these substances), to avoid dropping and losing small pieces about the laboratory;

(10) Sodium, potassium, and phosphorus must not be kept with other chemicals in the laboratory, but must be in the custody of the head teacher, who is responsible for keeping them in a locked compartment, of which he alone must retain the key. Special lockers are supplied for this purpose;

(11) When evening classes are held in the same laboratory, another supply of these materials must be similarly retained in the custody of the evening-school teacher;

(12) All bottles containing dangerous chemicals should be distinctly marked;

(13) The school-keeper must make a round of inspection every night after work is over in the laboratory, in order to make certain that all taps are turned off, and that there is no danger of fire;

(14) For the prompt treatment of burns and acid wounds, a bottle of carron oil should be kept ready for use in each laboratory or science-room.

N.B.—These regulations are to be printed in large type, mounted on cardboard, and hung in a conspicuous place in the laboratory.

The draught-closets are very important fittings in a chemical laboratory. If there are small draught-hoods or enclosures on the benches, as already mentioned, one closet to every eight or ten bench-places is generally found sufficient, otherwise the proportion should be somewhat larger. These closets should be two feet six inches to three feet long and about nineteen inches deep, with gas laid on inside. Great care should be taken to obtain a reliable and rapid extraction of the air in the closets that is not readily reversed by the general ventilation of the room. A gas-burner (not necessarily a Bunsen burner) placed within a vertical flue or pipe is the simplest way of obtaining independent action; the fullest advantage is then taken of the heat from evaporations conducted in the closet.

Now that electric current is becoming more and more readily obtainable, a small fan or blower is often adopted for this work. Where a number of flues or ducts are grouped together, special care must be taken to equalise the extraction by graduating their sizes. The various methods of dealing with the ventilation of both draught-closets and the laboratories themselves were fully dealt with in a paper given by the writer in January, 1904, and published in abstract in the building papers (*Builder*, for Feb. 5, and *Architect*, etc., for Feb. 12).

The pros and cons of the question of combining the laboratory and the lecture-room into one room cannot be discussed here, but it will be obvious that with a few modifications the laboratory can be easily made suitable for a certain amount of lecturing or demonstrating, in addition to the regular practical work. One lecture-room is usually made to serve for both the chemical and physical departments. The lecture-table can hardly be too long; plenty of space must be reserved for working the lantern which is now so largely used for lecture purposes as to be considered quite indispensable. A straight rake for the seats is generally adopted; the correct stepping of the seats on a hollow or isacoustic curve to ensure for each student an uninterrupted view of the experiments is not so usual.

Only the briefest space is left for reference to

physical laboratories. For physical work, what is most required is plenty of space both on the bench and, at other times, between them. Freedom from all vibration is much more necessary here than in chemical laboratories, and so is dryness for the apparatus. Certain of the operations demand particularly good light. As already mentioned, the laboratories are often on an upper floor in secondary schools, but sufficient steadiness can generally be obtained up there for the class of physical work that would be undertaken in these school laboratories. For all but very elementary work it is most convenient to have several tables that can without much difficulty be moved about the laboratory. In advanced laboratories it is usual to provide some particularly firm supports into the construction of which wood does not enter; these are for work with instruments that require to be accurately levelled and adjusted; they are generally slate or stone slabs, supported on brick or concrete piers, or built into the walls. For school laboratories the floor-area per student (including gangways, etc.) may be reckoned at about thirty square feet, but forty is advisable if all the apparatus is stored in the room.

A dark room is a necessity, not only for photography, but also for optical work. One can often be fitted-up under the raised seats of the lecture-room. The proper ventilation of it is frequently overlooked; it is not always realised

that light will not go round bends if there is no reflecting surface, but air will do so.

Some brief references have already been made to the provision of electric current for experimental work. This is a subject that requires the most careful consideration, even to the smallest detail. Unfortunately the difficulties of the service are greatly increased by the variation in voltage of the current suitable for the different purposes. For experimental work at the bench in chemical and physical laboratories currents up to twenty-five volts are perhaps the most useful, but wires carrying heavier currents are required for the arc lantern in the lecture-room, electric furnaces, etc., while at the lecturer's table it is convenient to have both high and low tension terminals. Frequently when a motor generator can be run from the supply mains, wires from it as well as from the storage cells are taken to the students' benches.

It is hoped that the foregoing suggestions and observations, brief and incomplete though they are obliged to be, may prove of some interest and assistance to those who have new laboratories to arrange and equip, or old ones to remodel.

THE END

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